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A. G. Chernitsky, and A. A. Loenko

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Biologiya zavodskoi molodi semgi posle vypuska v reku

A. G. Chernitskii, A. A. Loenko

Akademiya Nauk SSSR
Ordena Lenina Kol'skii nauchnyi tsentr im. S. M. Kirova
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Biology of Atlantic salmon juveniles after release from hatchery to river

A. G. Chernitsky[1] and A. A. Loenko

The USSR Academy of Sciences
The S. M. Kirov Scientific Centre in Kola (decorated with the Order of Lenin)
Murmansk Institute of Marine Biology
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[1] "Chernitskii" is the normal transliteration of the Russian name "Черницкий", according to the British-American Standard system. "Chernitsky" is the author's transliteration in the English translation of the title in the original text. [Tr.]

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The results are presented of studies on the fate of juvenile salmon that were released into natural conditions after being reared for 3 years in a fish hatchery. The causes of the low survival rate of the hatchery fish in the river and in the sea are analyzed. The release methodology is discussed on the basis of the authors' own data and the literature data.

The book is intended for ichthyologists, ecologists, and specialists in the fishing industry and in nature conservation. 22 illustrations, 56 tables, with a bibliography of 181 entries.

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INTRODUCTION

The establishment of a fish hatchery is the first idea that is dictated by a necessity to increase the population numbers of salmon, regardless of the cause leading to the decrease in this population, whether this be overfishing, pollution or hydraulic engineering construction.

The essence of hatchery production consists of the fertilization and incubation of the eggs, the rearing of the young fish and their release into natural conditions. Salmon rearing has a history that goes back two hundred years (Skatkin, 1962; Kazakov, 1982; Shustov, 1983). The development of the biotechnology was accounted for by the aspiration of fish culturists to achieve a sufficiently high survival rate of the juvenile fish. At the fish hatchery the problem of fish mortality has been combatted by creating conditions for maintaining the fry, by developing methods for treating their diseases and by improving their food, while it was hoped to decrease the mortality after release by rearing a vigorous product. The vigor of the juvenile fish was directly related to their dimensions and therefore, in order to increase the vigor, an endeavor was made to release larger fish, which led to an extension of the periods of rearing of the Atlantic salmon in fish hatcheries.

In the first stage of the history of salmon culture, eggs and sac fry were released from the hatcheries into natural bodies of water. In the second stage 2 - 4-month old underyearlings were released, while in the third stage 2 - 3-year old fish were released. The fourth stage is characterized by the release of juveniles that are ready to migrate into the sea, the downstream migrants. It was supposed that the rearing of juveniles to the downstream migrant stage would increase the numbers of salmon regardless of the productivity of the river. Already by the end of the sixties a group of specialists of the GosNIORKh [*Gosudarstvennyi nauchno-issledovatel'skii institut ozernogo i rechnogo rybnogo khozyaistva* - State Scientific Research Institute of Lake and River Fisheries] noted that biologically based methods for the rearing of juvenile fish to a stage "close to downstream migration" had been elaborated,

checked out under production conditions and implemented to a considerable degree in many Atlantic salmon hatcheries (Yandovskaya et al., 1968). These authors came to the conclusion that "at the present time it is already difficult to make any greater demands on science with regard to the development of methods for the rearing of Atlantic salmon" (Yandovskaya et al., 1968, p. 76). Nevertheless, even now, 20 years following such optimistic declarations, the effectiveness of salmon hatcheries in our country and abroad remains unsatisfactorily low.

Up to the present time the biotechniques for the hatchery rearing of the Atlantic salmon are considered as having been worked out in the main (Kazakov, 1982; Shustov, 1983; Gaston, 1988). The biology and requirements of the species in the freshwater stages of its ontogeny , from the egg to the smolt, have been studied to an adequate degree; the necessary equipment for fish culturing has been set up, and feeds and feeding regimes have been developed. This has allowed us to obtain high survival rates of the juvenile fish in fish hatcheries, exceeding by far the percentage survival for this same period under natural conditions. However, following their release into the natural conditions a considerable portion of the hatchery-reared juvenile fish die, which brings to nought the many years of work of the fish culturists. The data regarding a high survival rate of hatchery fish under natural conditions, presented by some investigators (Bogdanov and Shevtsova, 1978; Kazakov, 1981), were obtained only on some selected batches of limited volume of the most viable juvenile fish. The results of wide-scale international studies on the mass tagging of wild and hatchery-reared juvenile fish unequivocally indicate that the hatchery-reared fish has a much poorer survival rate under natural conditions than the wild fish. Of important significance to an understanding of the causes of the mortality of the hatchery-reared fish in natural conditions is the study of the biology of the fish after their release into the river and of the effect of the release method on the fate of the Atlantic salmon. Our book is concerned with these questions.

The idea for such studies belongs to E. L. Bakshtanskii, Senior Scientific Officer of the VNIRO (*Vsesoyuznyi nauchno-issledovatel'skii institut morskogo rybnogo khozyaistva i*

okeanografii - All-Union Scientific Research Institute of Marine Fisheries and Oceanography), who in 1978 organized an interdepartmental expedition to reveal the causes of the low effectiveness of the Kandalaksha fish hatchery. Workers from various organizations participated in the expedition: N. V. Safonov, V. I. Rozhdestvenskaya, V. A. Lepskaya, A. Yu. Zhuikov, A. A. Yarzhombek (VNIRO), M. Ya. Yakovenko, V. S. Isaev, V. M. Zadorina (PINRO - *Polyarnyi nauchno-issledovatel'skii institut morskogo rybnogo khozyaistva i okeanografii im. N. M. Knipovicha* - The N. M. Knipovich Polar Scientific Research Institute of Marine Fisheries and Oceanography), L. Ya. Shterman (*Zoologicheskii institut AN SSSR* - Zoological Institute of the Academy of Sciences of the USSR), E. G. Berestovskii, O. V. Karamushko (MMBI KNTs AN SSSR - *Murmanskii morskoi biologicheskii institut, Kol'skii nauchnyi tsentr, Akademiya Nauk SSSR* - Murmansk Institute of Marine Biology, Kola Scientific Centre, USSR Academy of Sciences), as well as the authors of the present book, who commenced this work while working in the Central Laboratory on the Production of Fish Stocks of the *"Glavrybvod"* [*Glavnoe upravlenie po okhranie i vosproizvodstvu rybnykh zapasov i regulirovaniyu rybolovstva Ministerstva rybnogo khozyaistva SSSR* - Main Directorate for the Conservation and Reproduction of Fish Stocks and the Regulation of Fisheries of the Ministry of the Fishing Industry of the USSR] and PINRO, and at the present time are working in the MMBI and the *"Murmanrybvod"*[2]. In 1979 the work was continued under the direction of E. L. Bakshtanskii who even in the following years, having resigned from direct participation in the expedition, always kept an eye on our plans and results, and continued to help us with valuable advice.

Many of the results obtained in the work on the Luven'ga river have already been published (Bakshtansky et al., 1979, 1980; Loenko and Chernitskii, 1980, 1984, 1985; Loenko, 1983, 1985 a, b, v; Chernitskii and Loenko, 1983; Chernitskii and Shterman, 1981; Chernitsky, 1985, 1986; Bakshtanskii and Nesterov, 1985; Safonov et al., 1985, 1990; Chernitskii, 1985 a, b; Leshcheva and Zhuikov, 1989 et al.), although the materials are

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[2] *Murmanrybvod* - acronym, probably for *Murmanskie upravlenie rybovodstva* - Murmansk Directorate of Pisciculture, or some similar name. [Tr.]

analyzed here for the first time in such volume and in such particular aspects. We are grateful to our colleagues for their assistance in the many years of investigations. It should be noted that the carrying out of so extended a study became possible thanks to the good offices of Professor I. A. Barannikova - the Director of the Central Laboratory of the *Glavrybvod*, G. I. Luka - the Director of the *PINRO*, Dr. G. G. Matishov - the Director of the *MMBI*, and K. N. Budanov - the head of the *Murmanrybvod*. Invaluable indeed was the daily assistance of the workers of the Kandalaksha fish hatchery, of A. P. Popov, its Director, and of N. I. Kuznetsov, the manager of the fish-breeding station.

Chapter 1. CHANGE IN CONCEPTS OF THE ROLE OF THE RELEASE IN THE BIOTECHNOLOGY OF SALMON REARING

Artificial rearing of fish began to be developed in the second half of the XIX century, in order to compensate for the catastrophic decrease in fish stocks in natural bodies of water. Already in the 1920s, however, some doubts arose as to the correctness of the high estimates of the effectiveness of fish propagation. Thus, an investigation of the situation of salmon propagation in 20 countries (USA, Germany, France, Sweden and others) showed that widescale fish breeding did not avert the drop in catches.

People began to seek a way out of the situation that had arisen by obtaining more viable juvenile fish, by extending the period of rearing in the hatchery. With the transition to rearing yearlings and later also downstream-migrants, the fish culturists encountered new problems. Individual studies, devoted to the release of the juvenile fish and to their fate, are lost in the mass of studies on ways for improving the biotechnology of the rearing in hatcheries. We found the first mention of the problem of the release in the XIX century: "A fish that has become accustomed to dead food will starve after being released" (Grimm, 1883). A resolution of a conference on fish breeding (part 1, paragraph 2.9), convened by the Department of Agriculture in 1913, stipulated that "in the selection of a site for the release of young fish it is essential to conform to the natural conditions: the release should be carried out only where young fish of corresponding age are present in nature" (*Postanovlenie* ..., 1914, p. 23). In 1933 A. I. Berezovskii wrote (Berezovskii, 1933) that the size of the return and the effectiveness of the artificial propagation depend on the method and the character of the release of the fingerlings. In these same years there appeared the first study, known to us, in which the problem of the release was not only proclaimed but also resolved (Otterström, 1938). Having analyzed the experience of Danish fish culturists on the release of Atlantic salmon parr, the author noted the most important factors that affected the fate of the released juvenile fish: the place and the time of the release, the number of fish released and their density in the river. The correct selection of the release site makes it possible for the young

fish to find shelter and food. The ideal release site is a section of river not wider than 1.5 m and not deeper than 0.5 m, with a moderate current and a gravelly bottom. Dependent on the selection of the time of the release are the dimensions of the fish and the degree of their provisioning with food. The numbers of fish released should correspond to the conditions in a specific river. Apparently it was namely this author who introduced the concept of "nutritive capacity", which served as the precursor of the contemporary concept of "acceptance capacity" – the maximal number of juvenile fish which may exist in a given section. He pointed to the necessity, in calculating the acceptance capacity of a river, of taking into account the presence in the river of wild juvenile Atlantic salmon and sea trout.

Nevertheless, even 12 years later L. M. Nusenbaum noted that the weakest link in the hatchery production of the Atlantic salmon remained up until that time the final stage in the operation - the release of the young fish" (Nusenbaum, 1950, p. 127).

Even 23 years later D. Power (1973) , on the basis of a detailed investigation of several salmon rivers, proposed a quantitative approach for calculating the acceptance capacity of rivers that were designated for the release of parr. As a basis he accepted a productivity of 14 kg of juvenile salmon per 1 hectare of river. Subsequently there were introduced several coefficients, depending on the particular characteristics of a specific river (Table 1).

The necessity of taking into account the acceptance capacity of a section of river for the release of parr is corroborated by the fact that the released parr do not spread out far from the point of release (Galkin, 1961; Petrenko, 1964; Symons, 1969; Mitans, 1970; Shustov, 1983, and others). The release of parr in large batches, without taking into account the acceptance capacity, leads to the death of the fish in the river, to a forced migration of the parr into the sea, where there are no chances of survival for the unsmolted[3] fish (Harris, 1978; Bakstansky et al., 1979; Shustov et al., 1981; Smirnov et al., 1977, 1983; Shustov, 1983; Segarich, 1989). The fundamental principles for the release of smolts were formulated by B. Carlin (1955). The return from 17 thousand tagged (with underhanging tags)

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[3] "Unsmolted fish" is used here as a translation for the neologism "nesmoltifitsirovannykh ryb" in the Russian text, obviously referring to the fish that have not yet passed into the smolt stage. [Tr.].

Table 1

Calculation of the productivity of salmon rivers

Index	Correction coefficient
1	2
Bottom of river	
Movable gravel	0.2
Sand (ø less than 1 mm)	0.4
Only gravel (ø less than 1 cm)	0.8
Large and small gravel (ø up to 5 cm)	1.0
Same + some individual stones	1.2
Stones (ø more than 5 cm)	1.4
Width of river	
Less than 3 m	2.0
From 3 to 5 m	1.1
From 5.5 to 11 m	1.0
More than 11 m	0.9
River valley	
Open section with discrete groups of trees	0.7
Low growth forest up to 4.5 m in height	0.9
Forest with more than 3 species of trees more than 5 m in height	1.0
Fields with discrete sections of forest	1.1
Fields without forest	1.3
Predominant species	
Loach	0.8
Salmon	1.0
Sea Trout	1.2
Quality of water	
Very turbid water, visibility less than 20 cm	0.4
Not very transparent, cold water	0.7
Pure transparent cold water	1.0
Geographical latitude	
70° lat. N.	0.9
69° lat. N.	1.0
67° lat. N.	1.2
60° lat. N.	1.4
Coefficient of correlation of the productivity of the river with the data of the field studies	
Investigations conducted up to July 20th	0.8
Investigations conducted after August 15th	1.2

smolts of the Baltic salmon allowed data to be obtained for comparing different variants of release. It was found that it is best to release smolts in the spring, rather than in the autumn;

the return of 2+ smolts was higher than that of 1+ smolts, and among smolts of the same age the larger smolts gave a better return. In this same study the effectiveness of the release of smolts directly into the Baltic Sea was demonstrated.

In later studies all of these conclusions were corroborated on more than one occasion. Thus, numerous studies have shown that with an increase of the length of the fish by 1 cm there is an increase in the return: by 1% (Petrenko, 1976; Ritter, 1977), by 1.3% (Isaksson, 1976), by 1.7% (Eriksson, 1988), by 2% (Larson H. O., 1977), by 2.2% (Christrensen, 1982), by 2.8% (Osterdahl, 1964), by 3.6% (Gudjonsson, 1970) and even by 5% (Lindroth, 1977). According to other data there is an optimal size of the smolts, which ensures the maximal return. For the 1+ smolts this is 12.5 - 14 cm, and for the 2+ smolts it is 14 - 18 cm. With an increase in their length above 18 - 20 cm the return decreases once more (Peterson, 1973; Johansson, 1981).

The increase in the survival of the salmon, associated with the increase in size of the smolts, reflects the fact that small smolts comprise the optimal prey for the majority of the predators. The predator selects comparatively small prey, independently of what is its absolute size (Larsson P. -O., 1977). On the other hand, the difference in the values of the length optima of smolts of different age indicates that apparently it is not the actual length of the fish by itself but rather the rate of growth that determines their survival. The return from the smolts at an age of 2+ is 4 - 10 times higher than that from the 1+ smolts (Gudjonsson, 1973; Vickers, 1977).

Numerous experiments on the tagging of smolts have shown that the survival of the smolts depends on the time of their release (Peterson et al., 1972). In the first place, even large silvery juveniles, released into the river a month after the termination of the downstream migration of the wild juveniles, will not pass into the migration stage. Secondly, in natural conditions the smolts pass from the river into the sea in the period of the most favourable combination of abiotic and biotic factors, which promote the maximal survival of the fish. This period is called the migration window (Saunders and Beile, 1980). For this reason the maximal return of the adult individuals may be obtained from the release of juveniles in

these windows, when the best guarantee of food is also present. The optimal time for the release is that at which one ensures the entry of the juvenile fish into the river ecosystem or the marine ecosystem at the moment when a good food base is conducive to their growth and survival (Bilton et al., 1983).

Thus, the principal causes of an effective release of hatchery-reared juvenile fish have been formulated in the scientific literature: taking into consideration the acceptance capacity in the release of parr, and coinciding with the migration window in the release of smolts. However, in the documents intended for setting norms these principles were practically not taken into account, which is revealed in an examination of the instructional materials on salmon rearing.

The 1955 instructions (Vernidub and Yandovskaya, 1955), which for a long time remained the basis for salmon rearing in the North and North-West, do not concern themselves at all with questions about the release of the hatchery production. The 1958 instructions (Protasov, 1958), which are devoted to the salmon of the Kura river, describe in detail the technical measures for transporting the juveniles to the release sites but they ignore the biological aspects of the release of the juvenile fish.

One of nine chapters of the principal part of the 1963 instructions (Smirnov, 1963) is devoted to the methodology of the release of the juvenile fish. In it are examined in adequate detail the specific characteristics of the smoltification of Pacific salmon and the abiotic conditions conducive to the downstream migration of the juvenile fish into the sea, and important recommendations are given on the distribution of the released juvenile fish in different sections of the river, depending on the degree to which their migration behaviour has been established. A. I. Smirnov advised that the juvenile fish that had not reached the downstream migrant stage be taken for release into sections of the upper reaches of the river, in order to avert the premature carrying-out of the fish into the sea. Furthermore, with a high release the juvenile fish more completely assimilate the food resources of the river. The instructions draw the attention of fish culturists to the careful selection of the specific

biotope for the release of juvenile fish of a particular species, and to the inadmissibility of releasing a large number of fish in one place.

Much less attention was given to questions concerning the release of juvenile fish in the instructions on the rearing of the Baltic salmon (Malikova et al., 1969). It was pointed out that special attention should be given to the time and the place of the release into the river of juvenile salmon that had attained the downstream migrant stage. Specific recommendations are reduced to the following: "The release of juvenile fish that had attained the downstream migrant stage by the middle of May may be carried out in the river, from where they still have time in the same year to migrate downstream into the gulf, at the same time with the juvenile fish of the natural spawning. The release of juvenile fish that had attained the downstream migrant stage in the middle of the summer (June - July) should be carried out in sections of the river near the estuary, rather than higher up, in connection with the fact that the water temperature in the river increases more rapidly than in the sea, and the temperature barrier that is formed will impede the downstream migration of the juvenile fish from the river in the same summer... The salmon that are released from the fish hatcheries into the gulf in the stage of the silvery parr in the middle of the summer have time to become acclimatized in the new conditions by the autumn... The juvenile Baltic salmon that have been reared by the middle of the summer to the stage of the silvery parr should not be held in the hatchery for the purpose of rearing two-year-old downstream migrants" (Malikova et al., 1969, p. 17 - 18).

The instructions that were published in Sweden (Peterson et al., 1972), out of all of the aspects of the problem of release, dwell only on the selection of the time of the release, since the studies of the Swedish fish culturists had shown that the time of the release is the main factor determining the survival of the juvenile fish. They recommend that the young fish be released directly from the culturing installations, without transportation.

The instructions on the rearing of juveniles of the freshwater salmon (Ryzhkov et al., 1973) do not consider the problem of the release. In the 1979 instructions, developed by the GosNIORKh for salmon hatcheries in the North and North-West (Yandovskaya et al., 1979)

the release of the juvenile fish has been separated out into a special chapter, the main content of which pertains to the transportation of the juvenile fish. Only the first and last paragraphs are devoted to the release propar. "The release should be carried out when the water temperature rises to 3 - 6°, approximately two to three weeks prior to the commencement of the period of the natural downstream migration. For the hatcheries in the North-West of the RSFSR the release should be accomplished at the end of April or the beginning of May; in the North - in May. For every hatchery the periods for the release are defined more precisely on the basis of data obtained over many years. It should be mentioned that an early or a late (at the height or at the end of the natural downstream migration) release leads to a diminishment of the commercial return... (p. 78). "The release of downstream migrant juveniles (silvery smolt[4]) and of juveniles that are close to the downstream migration (silvery parr 2.3) is carried out in sections of the river near the estuary at a calculated density of 10 - 15 individuals per 100 m^2 area. Juvenile fish with less intensive silvering (silvery parr 1, juveniles with signs of silvering) are released in the lower reaches of the river at a calculated density of 5 - 7 individuals per 100 m^2 area" (p. 80).

In the handbook that was published in 1988 on the propagation of the Atlantic salmon for the restoration of stocks (Gaston, 1988) it is pointed out that the salmon is most vulnerable when it first adapts to the natural conditions and therefore a proper technique for the release is essential. In this handbook, however, the main consideration is devoted to problems of transportation of the juvenile fish. It is acknowledged that the ideal solution for smolts would be their direct release from the hatchery installations into the river. It is necessary to set up a release tank close to the river into which the fish can get either by themselves or with water pumped over through pipes, or to which they are brought in containers. A basin or channel with river water can serve as such a release tank. The smolts should have the opportunity to leave the release tank freely, and therefore the partition that separates it off from the river is made not to the whole height of the column of water but somewhat lower, since the smolts stay in the upper layers of the water. As Gaston himself

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[4] For a discussion of the terminology see page 30 of this translation. [Tr.]

points out, at the present time there is no confirmation that the application of release tanks increases the return of the adult fish, but their use does allow one to observe the migration of the juvenile fish and increases the survival rate of the smolts following their release.

At the time when the last of the mentioned instructions were being formulated, serious investigations were already being carried out in the USSR on the biology of hatchery-reared juvenile Atlantic salmon after their release into the river. In the first instance these are the studies of L. A. Petrenko (GosNIORKh, Leningrad), A. R. Mitans (BaltNIRKh [*Baltiiskii nauchno-issledovatel'skii institut morskogo rybnogo khozyaistva i okeanografii* - Baltic Scientific Research Institute of Marine Fisheries and Oceanography], Riga), and Yu. A. Smirnov, Yu. A. Shustov and I. L. Shurov (*Institut biologii Karel'skogo filiala AN SSSR* - Institute of Biology of the Karelian Branch of the Academy of Sciences of the USSR, Petrozavodsk). Later, when our studies on the Luven'ga river were started, there was published the first report in the Soviet literature that generalized the data available up to that time on the biological aspects of the release of juvenile salmon (Bakshtanskii and Chernitskii, 1983). Then also appeared the "*Rekomendatsii po vypusku molodi atlanticheskogo lososya i kumzhi*" ["Recommendations on the release of juveniles of the Atlantic salmon and sea trout"] (Bakshtanskii et al., 1981) and "*Metodicheskie ukazaniya po vypusku molodi atlanticheskogo lososya* ..." ["Methodological instructions on the release of juveniles of the Atlantic salmon ..."] (Kostylev and Ermolaev, 1983). In the first of these studies consideration is given to the theoretical aspects of the problem of the release of salmon juveniles, while in the second a brief characterization is presented of the salmon rivers in Karelia and general recommendations are given for optimizing the sites, volumes and times of release of the fish-hatchery production. However, a specific methodology for the release of juvenile fish from fish hatcheries does not exist up to the present time.

Chapter 2. STUDY REGION, MATERIALS AND METHODS OF INVESTIGATION

2. 1. Luven'ga river

The Luven'ga (old spelling - Luvenga) is one of the small rivers of the Kola peninsula. It is 29 km in length, with a catchment area of about 200 km^2, a 180 m drop of the river and an average slope of 6.1%. The river flows out of the Verkhniy Luven'gskiy [Upper Luven'ga] Lake and flows into the Kandalaksha Bay in the Beloye More [White Sea].

The Luven'ga is a lacustrine-fluvial system (Figure. 1). Two[3] lakes divide up the river channel into three fluvial sections: the Verkhnyaya Luven'ga [Upper Luven'ga] (7 km in length), the Srednyaya Luven'ga [Middle Luven'ga] (8 km in length) and the Nizhnyaya Luven'ga [Lower Luven'ga] (14 km in length). The characteristics of the lakes are presented in Table 2. A few other small lakes provide the source of the tributaries of the Luven'ga. The river channel is moderately sinuous. Its width at the source is 4 m, while in the lower-lying sections it ranges from 6 to 17 m. The maximal depth of the river is 2.5 m and the bottom is stony. The shores are steep, sandy-stony, forested, 4 - 12 m in height. The river is fed mainly by snow. The Luven'ga freezes in October - November, while the break-up occurs in April - May. The river is not polluted by any discharges.

In the Luven'ga lacustrine-fluvial system we have found 12 species of fishes (Table 3). 38 species of invertebrates have been found in the benthos of the river (Zadorina, 1985). Distinguished by the numbers of species are the larvae of chironomids and caddis flies. Predominant in the drift of the Luven'ga are the larvae of black flies, the nymphs of mayflies and adult insects. Dominant in the summer zooplankton are rotifers (88% of the population numbers or 95% of the biomass of all of the planktonic organisms); in second place are the copepods (10 and 3%), while the cladocerans comprise about 2% both as to the population numbers and the biomass (Kruglova, 1987). Muskrats live in the river, while mink, mergansers, terns, gulls and kingfishers hunt in the river.

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[3] Sic. Should surely be "three" here. [Tr.]

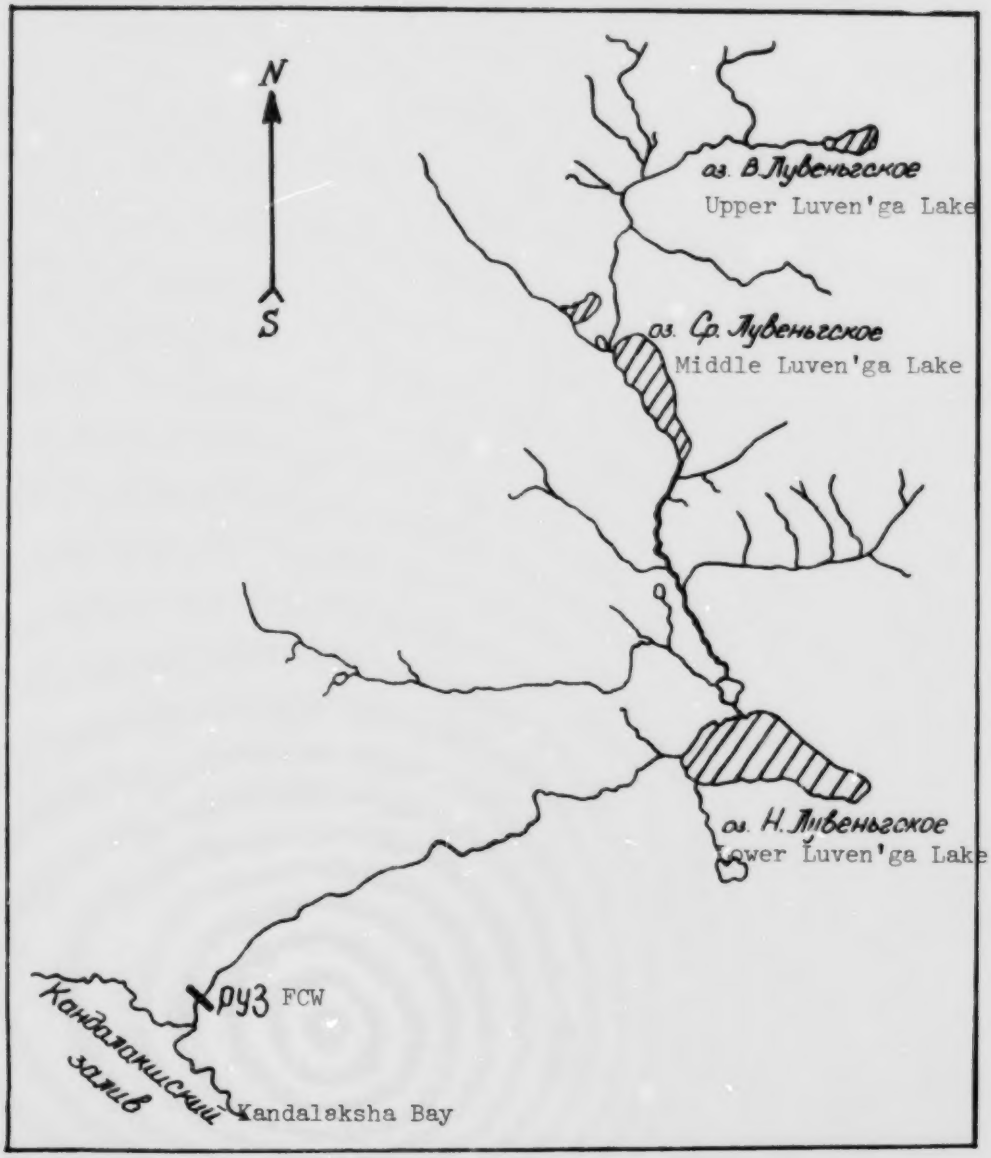

Рис.1. Система реки Лувеньга.

Figure 1. Luven'ga river system

The importance of the different sections of the river in the natural reproduction of the Atlantic salmon varies. In 1982 we established three fish-counting weirs (FCW[6]) for counting the juveniles of the Atlantic salmon that were migrating to the sea. The first FCW was set up near the inflow of the Middle Luven'ga river into the lake; the second - on the

[6] The Russian abbreviation is РУЗ [RUZ] - *rybouchetnoe zagrazhdenie*. [Tr.]

Table 2.

Characteristics of the lakes of the Luven'ga river system

Lake	Length, km	Width, km	Area, km^2	Depth, m	
				prevailing	maximal
Verkhnee Luven'gskoe [Upper Luven'ga]	1.2	0.4	0.20	2.0	3.1
Srednee Luven'gskoe [Middle Luven'ga]	3.0	0.5	0.75	5 - 6	15.2
Nizhnee Luven'gskoe [Lower Luven'ga]	3.0	1.5	2.2	15 - 20	32.5

Table 3.

Ichthyofauna of the Luven'ga river system

Fish	Section of system					
	Up. Luven'ga river	Mid. Luven'ga river	Low. Luven'ga river	Up. Luven'ga lake	Mid. Luven'ga lake	Low. Luven'ga lake
Atlantic salmon (*Salmo salar*)	+	+	+	-	+	+
Sea trout (*S. trutta*)	+	+	+	?	+	+
Arctic char (*Salvelinus alpinus*)	-	-	-	-	?	+
Whitefish (*Coregonus lavaretus*)	-	-	-	+	+	+
Cisco (*C. albula*)	-	-	-	+	+	+
Perch (*Perca fluviatilis*)	-	-	-	+	+	+
Pike (*Esox lucius*)	-	-	-	+	+	+
Burbot (*Lota lota*)	+	+	+	+	+	+
Smelt (*Osmerus esperlanus*)	-	-	-	-	-	+
Threespine stickleback (*Gasterosteusaculeatus*)	-	-	+	-	-	+
Ninespine stickleback (*Pungitius pungitius*)	-	-	+	-	-	+
Lamprey (*Lampetra fluviatilis*)	-	-	+	-	-	-

NOTE. + - present, -- absent, ? - present according to unverified data of fishermen.

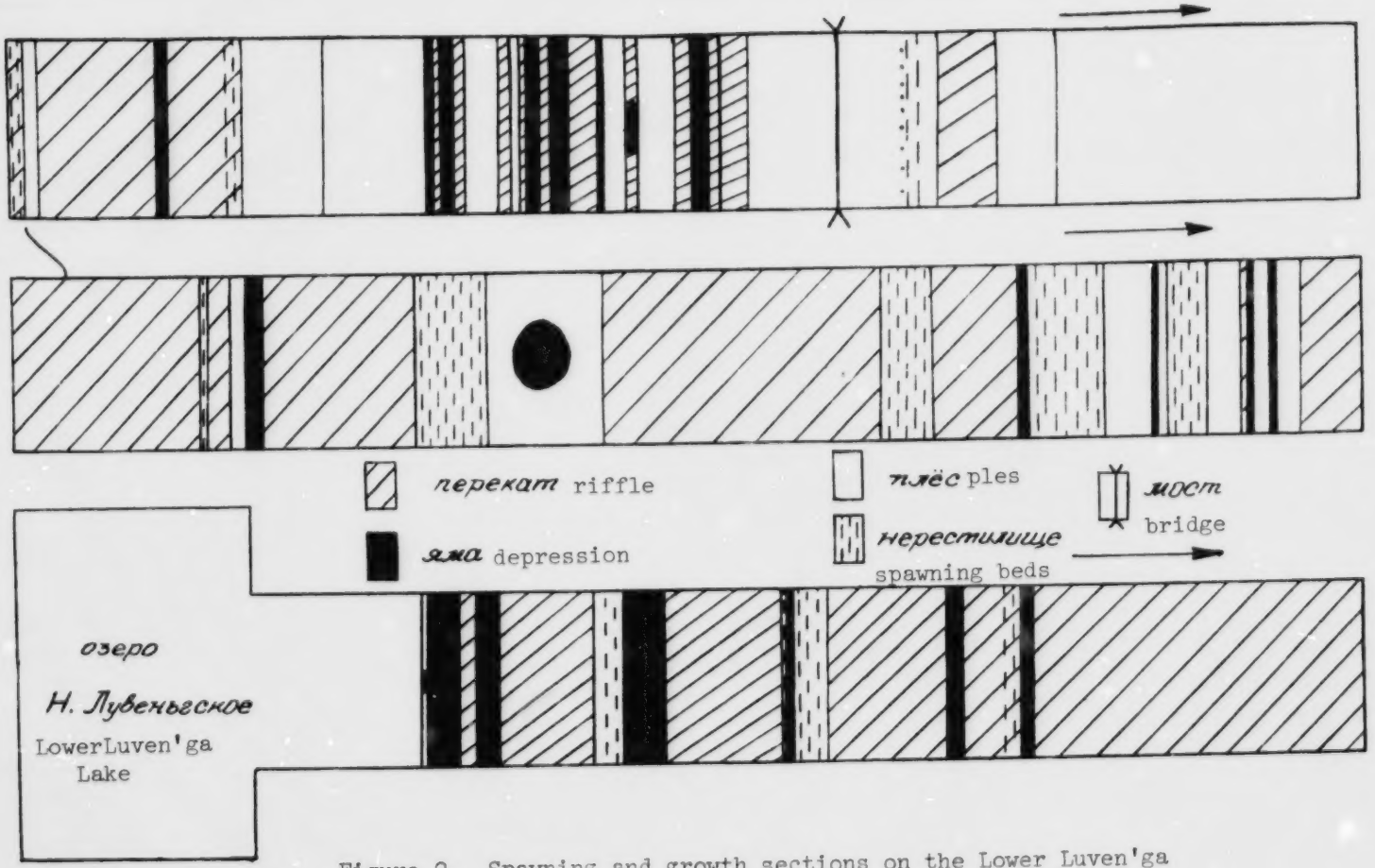

Figure 2. Spawning and growth sections on the Lower Luven'ga
Рис. 2. Нерестово-выростные участки Нижней Лувеньги.

Lower Luven'ga river, 150 m below the lake, while the third was set up half a kilometer above the mouth of the Lower Luven'ga. All three FCWs completely covered the cross section of the river. The count of the smolts, which continued over the entire period of migration, showed that the Middle Luven'ga river produced only 4% of all of the migrating wild juvenile fish.

Taking into consideration the importance of the Lower Luven'ga river to the natural reproduction of the salmon, we carried out a survey of the spawning and growth sections of the river (Figure 2). Of the 14 km extent of the Lower Luven'ga river, 3.17 km (23%) belong to "plës"[7] sections, 1.53 km (11%) comprise pits and depressions, while 9.28 km (66%) comprise riffles. The area of riffles comprises 124011 m^2, of which 17187 m^2, or 13.9% of the total area of the riffles, comprise the spawning beds.

The organized catch of salmon in the Luven'ga river is carried out by the Kandalaksha fish hatchery, which has a fish-breeding station for the catching of the adult fish and the collection of the genital products. In recent years 1/3 of the fish separated out prior to spawning were released from the holding tank at the fish-breeding station for natural reproduction. Illegal fishing for salmon has been recorded in sections near the estuary, in the pits on the river, and also in the lakes of this system. In the Luven'ga river the juveniles of the Atlantic salmon are released by the Kandalaksha fish hatchery.

2. 2. Kandalaksha fish hatchery

The Kandalaksha experimental fish hatchery is located in the town of Kandalaksha in Murmansk oblast on the shore of the Niva river, which was an important salmon river of the White Sea. In 1930 the first hydroelectric power plant of a cascade was constructed on the Niva river, which undermined the possibility of the natural reproduction of the Niva salmon. In order to compensate for the loss in the production of salmon, a salmon fish hatchery was

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[7] The Russian word "plës", often translated by "reach", refers especially to a moderately deep to deep slow portion of a river, between sandbars or riffles, characterized by an even bottom. [Tr.]

built on the left bank of the old river channel. The decision on the construction of the hatchery was made on the 7th of December 1951. The project was developed by the *Gidrorybproekt* Institute [*Gosudarstvennyi institut po proektirovaniyu gidrotekhnicheskikh, rybovodno-meliorativnykh i prudovykh sooruzhenii* - State Institute for the Planning of Hydraulic Engineering, Fishery Improvement and Pond Structures]. The construction was carried out from 1954 to 1958 by the *NivaGESstroi* [Niva Hydroelectric Power Plant Construction] Trust. The hatchery was put into operation in March of 1958. The projected capacity was an annual release of 100 thousand individual yearling Atlantic salmon. In 1964 the first batch of third-year downstream migrants was released.

Following a reconstruction, the capacity of the hatchery reached a level of 120 thousand third-year fish, for the rearing of which the following eqipment is present: 2 units of the Williamson incubation apparatus, with a total capacity of 600 thousand eggs; 40 wooden nursery units; 36 concrete basins, with a total area of 38.5 m^2; 42 ITsA 1 [8] plastic basins, with a total area of 94.5 m^2; 4 ITsA 2 plastic basins, with a total area of 12.8 m^2, and 10 earthen ponds, with a total area of 5.3 hectares.

The hatchery came into operation after the extermination of the Niva salmon run. When the hydroelectric power plant cascade was put into operation a drastic change occurred in the hydrological and hydrochemical regime of the river. The old channel below the Niva-3 hydroelectric power plant is in an almost dried-up state and and is fed only by some small left-bank streams and some inflow of ground waters. The small water flow and its distribution in a thin layer over the whole channel creates favourable conditions for contamination by melt waters and industrial and communal run-off. Because of this, cases of poisoning and mortality of the juvenile fish are constantly being found in the Kandalaksha fish hatchery. This situation is also intensified by the fact that the water intake of the hatchery is located below its own water discharge.

Up until the middle of the seventies the hatchery operated according to the following scheme: the eggs were procured on the Kola river and to a lesser degree on the Luven'ga

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[8] ИЦА - ITsA - unknown abbreviation (could be ICA?). [Tr.]

river; the incubation of the eggs and the rearing of the juveniles were carried out in the water of the Niva, while the main part of the production was exported to the Luven'ga and Kolvitsa rivers. Individual batches were released into the Tiksha, Niva and Kanda rivers.

In Table 4 are presented data on the survival of the juveniles of the Atlantic salmon during the rearing process in the Kandalaksha fish hatchery.

Table 4.

Survival (%) of Atlantic salmon juveniles of the 1966 - 1980 generations at various stages of rearing in the Kandalaksha fish hatchery (Loenko, 1986)

Stage of rearing	Standard, %	Average	Minimal - Maximal
Incubation of eggs	92.0	90.9	82.2 - 97.0
Holding and initial growing of underyearlings	74.4	74.4	23.0 - 94.1
Growing of underyearlings	70.0	42.7	11.9 - 80.4
Overwintering of underyearlings	80.0	88.2	31.5 - 98.0
Summer growing of second-year fish	80.0	72.7	62.1 - 93.3
Overwintering of second-year fish	94.0	92.8	74.9 - 99.0
Summer growing of third-year fish	95.0	87.3	87.3 - 100.0
Overall from incubation of eggs to third-year fish	27.4	17.0	2.6 - 40.2

2. 3. Release of juvenile fish

In 1978 there were released into the Luven'ga 41.3 thousand juveniles of the Atlantic salmon at an age of 2+. The release was carried out in seven batches directly from the live-fish truck at a distance of 1.3 and 3.9 km from the mouth (Figure 3). The first batch was

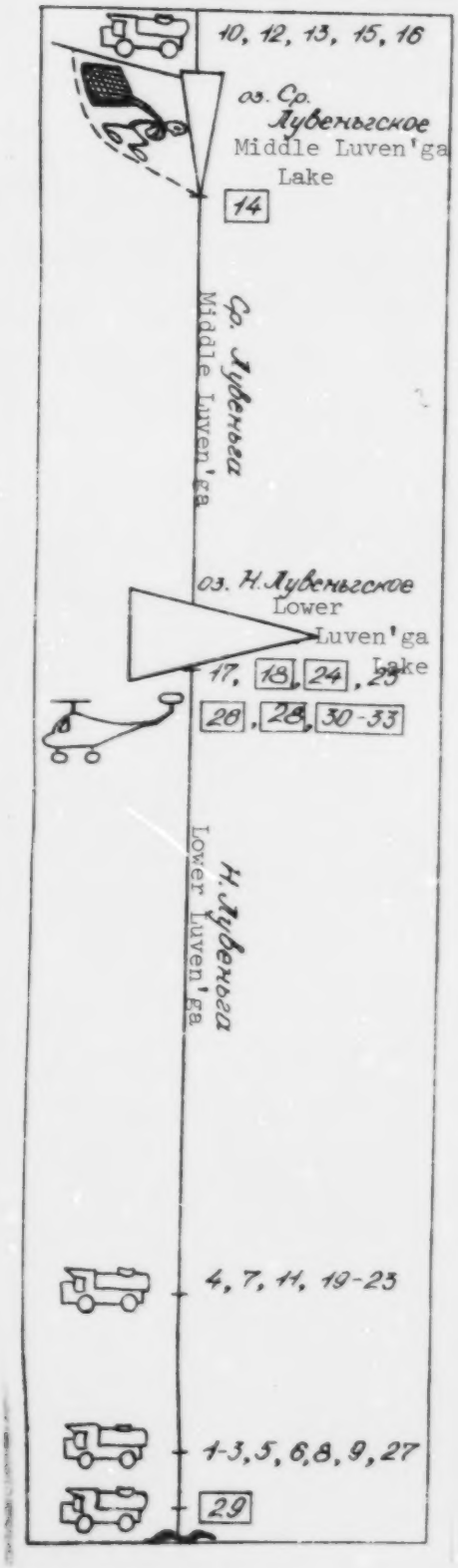

Figure 3. Scheme of the transportation and distribution of the released juvenile fish. The figures denote the numbers of the batches; the rectangles denote the batches that were released by way of the holding nets.

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released on June 23rd, the last - on August 15th. The size of each batch, the average weight of the released juveniles and the water temperature at the time of the release are shown in Table 5. In order to work out methods for recognizing the hatchery fish in the river, all of the juveniles of the first batch were stained with a vital dye.

In 1979 there were released into the Luven'ga 58.6 thousand salmon at an age of 2+. The release was carried out in two batches. In 1980 juvenile fish from the Knyazhegubskii hatchery were released into the Luven'ga , numbering 5.1 thousand individuals aged 2+. The fish were released in two batches at different distances from the mouth. Batch 10 was conveyed by a live-fish truck to the Upper Luven'ga river and released on June 16th directly from the truck 200 m above the confluence into the Middle Luven'ga Lake (Figure 3) at a distance of 23.5 km from the estuary. Batch 11 was released 4 days later from the live-fish truck 3.9 km from the mouth of the river. In order that the salmon from batches 10 and 11 could be distinguished, the fish were tagged with individual underhanging tags of different colour.

Table 5.

Characteristics and conditions of release of juvenile salmon.

Batch No.	Date of release	Amount, fish	Average mass, g	Distance from mouth, km	Temperature of water in river, °C
1	23. 06. 78	1300	21.0	1.3	12
2	27. 06. 78	8000	18.5	1.3	9
3	29. 06. 78	6530	18.5	1.3	15
4	12. 07. 78	5430	18.5	3.9	13
5	17. 07. 78	10050	18.5	1.3	11
6	28. 07. 78	1000	12.0	1.3	15
7	15. 08. 78	10000	20.5	3.9	10
8	8. 06. 79	18400	17.6	1.3	5
9	10. 07. 79	40200	18.0	1.3	16
10	16. 06. 80	2477	29.8	23.5	11
11	20. 06. 80	2624	29.8	3.9	13
12	8. 06. 81	10000	22.2	23.5	8
13	15. 07. 81	26500	18.5	23.5	14
14	25. 06. 82	4500	18.7	21.3	5
15	25. 06. 82	4500	18.7	23.5	5
16	25. 06. 82	5500	18.7	23.5	5
17	22. 07. 82	24900	18.0	14.0	13
18	23. 06. 83	7800	28.3	14.0	11
19	2. 07. 83	1000	17.6	3.9	14
20	2. 07. 83	1000	17.7	3.9	14
21	20. 07. 83	12216	18.1	3.9	14
22	29. 07. 83	1000	20.0	3.9	14
23	29. 07. 83	1000	20.0	3.9	14
24	8. 06. 84	7278	16.7	14.0	9
25	3. 07. 84	12500	15.5	14.0	13
26	28. 06. 85	9000	26.1	14.0	9
27	15. 07. 85	1500	23.7	1.3	15
28	20. 07. 85	18700	23.3	14.0	16
29	22. 06. 86	1756	30.1	0.5	-
30	24. 06. 86	9344	30.1	14.0	14
31	26. 07. 86	20300	18.8	14.0	15
32	29. 06. 87	24700	21.8	14.0	15
33	18. 07. 87	18600	19.6	14.0	11

In 1981 a release was made, in two batches, of 36.5 thousand juvenile fish (Table 5). In 1982 a release was made, in four batches, of 39.4 thousand salmon. The juveniles of Batch 14 were marked by trimming the anal fin. The fish were conveyed by a live-fish truck to the Middle Luven'ga Lake, placed into a holding net on the 20th of June and towed down,

in the holding net, to the source of the Middle Luven'ga river. After 5 days, on June 25th, the holding net was opened and the fish were able to leave it freely. In Batch 15 the fish were tagged by trimming the ventral fin, while in Batch 16 the adipose fin was trimmed. The fish in these batches were released from the live-fish truck in the mouth of the Upper Luven'ga river, as was Batch 10. Batch 17 was conveyed by a helicopter in polyethylene sacs to the source of the Lower Luven'ga river and released directly from the sacs into the river (Figure 4).

In 1983 a release of 24 thousand fish was made in six batches. Batch 18 was conveyed in a helicopter to the source of the Lower Luven'ga river, placed in a holding net with an area of 6 m^2 and on June 23rd, four days later, released in groups of 200 - 300 fish in an hour. To provide a way out for the fish we lowered the front wall of the net somewhat below the water surface. Included in batches 19 and 22 were fish that were used in experiments in the Institute of Biology of the Karelian Branch of the Academy of Sciences of the USSR on the training of juvenile fish prior to release (Shchurov et al., 1986a). Included in Batches 20 and 23 were the fish that served as the controls. The release were made on July 2nd and 29th from the live-fish truck; Batch 21 was released from the live-fish truck on July 20th. In Batches 21 - 23 there were many parr. 19.8 thousand juvenile fish were released in 1984 in two batches. Batch 24 was conveyed by helicopter to the source of the Lower Luven'ga river, and placed into a holding net from which the fish escaped within the first 24 hours. Batch 25 was released into the river directly from the helicopter.

In 1985 three batches of juvenile salmon were released, totalling 29.2 thousand fish. Batch 26 was released from the helicopter into a holding net in the channel. The fish began to escape from the holding net on the first day. In Batch 27 were included fish which had been subjected to experimental treatment in the Kandalaksha fish hatchery by research workers of the VNIRO (Safonov et al., 1988). After the experiments were terminated the fish were released from the live-fish truck. Batch 28 was conveyed on July 16th to the holding net in the channel. On July 20th the holding net was opened and the juvenile fish began to

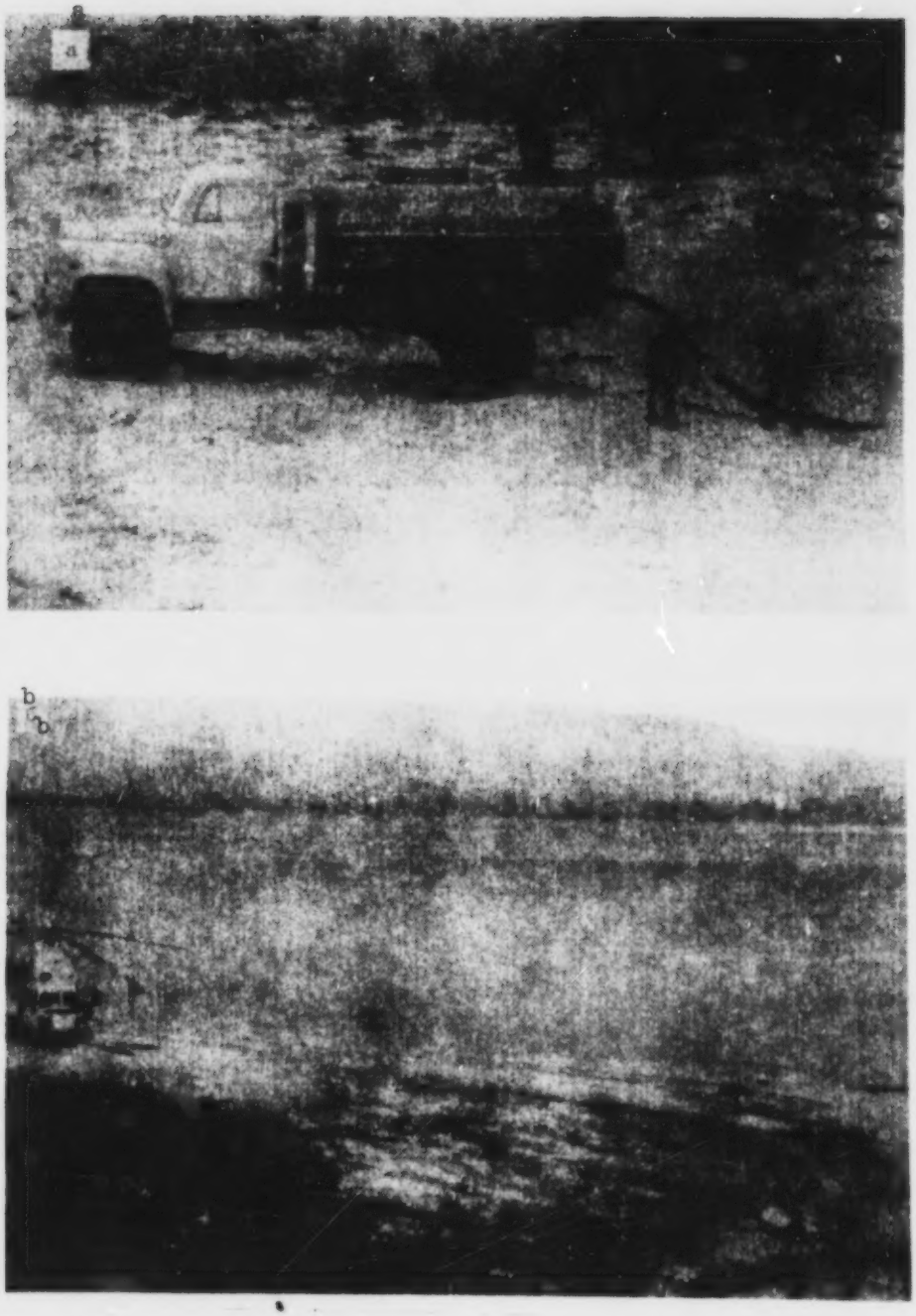

Рис.4. Выпуск молоди.

а – выпуск из живорыбной машины; б – перевоз мешков с молодью, доставленных вертолетом; в – выпуск молоди из мешков в русловой садок.

Figure 4. Release of juvenile fish.

a - release from live-fish truck; b - transfer of sacs with juvenile fish, conveyed by helicopter; v - release of juvenile fish from sacs into holding net in channel [on following page - Tr.]

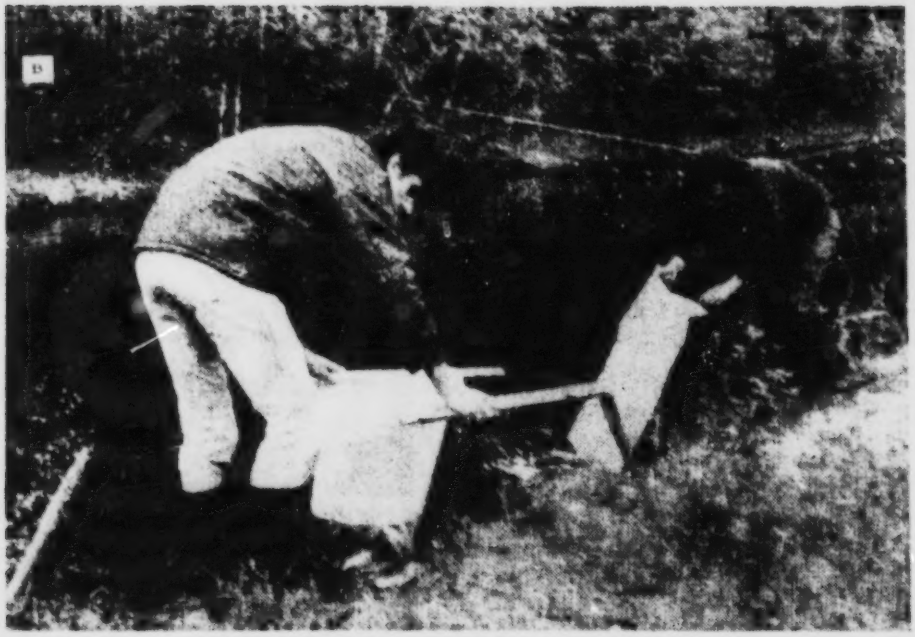

Figure 4, v.

migrate. In 1986 into the Luven'ga river were released 31.4 thousand juvenile fish in three batches. On June 8th Batch 29 (fish tagged with magnetic tags) was placed into a holding net with an area of 6 m^2, that had been set up 0.5 km above the mouth; on June 22nd the holding net was opened. Over the course of the following week the juvenile fish escaped from the holding net into the sea. Batch 30 was conveyed by helicopter to the source of the Lower Luven'ga river and placed into a holding net in the channel on June 24th. The holding net was opened on June 28th. Batch 31 was placed into this same holding net on July 24th, and on July 26th the net was opened.

In 1987 there were released into the Luven'ga river 43.3 thousand juvenile fish, in two batches. Batch 32 was released by way of the holding net in the channel. The fish were placed in the holding net on June 24 - 26th, the holding net was opened on July[9] 29 but even prior to this the fish began to escape through the lower wall of the holding net. Batch 33 was transported by helicopter on July 15th to the same holding net in the channel. The

[9] Sic. However, should probably be "June" here. See Table 5. [Tr.]

holding net was opened three days later but some of the fish had escaped from it prior to this. The fish from these 33 batches, together the wild smolts that were migrating in these same years, served as the material for our studies.

2. 4. Methods of obtaining the characteristics of the fish

The data on the numbers and mass of the juvenile fish released from the hatchery were taken from the release records. As a rule, the control seinings that were carried out before the release were done with our participation.

In order to count the juvenile fish migrating from the river, a fish-counting weir (FCW - Figure 5a) for the juveniles was set up 500 m above the mouth of the river. The walls of the weir, made of 10 mm netting, completely covered the cross section of the river channel. Sown into the wall was a single-bodied fyke made of 10 mm netting, into the end of which was sown a wooden box, the fish trap, owing to which the traumatization to the juvenile fish, poured out of the fyke during the counting, was reduced. Every day the walls of the FCW were cleaned by divers, and even twice a day at high water. During the cleaning a check was carried out on the integrity of the netting fabric and its contact with the bottom, and repairs to the walls were carried out. The FCW was set up prior to the start of the migration of the juvenile salmon from the river and it was taken down after the migration was terminated. This type of FCW allowed us to take stock of practically all of the juvenile fish migrating from the river into the sea. The juvenile fish that got into the FCW accumulated in the body of the fyke, from where, during the checking, they moved into the fish trap box from which, together with the water, they were poured into the holding net and remained there until the sorting, counting and other studies. The FCW was checked from 1 to 17 times a day, depending on the intensity of the migration.

During the count the juvenile fish were divided into three groups: hatchery, overwintered and wild. The smolts that were the progeny of the natural spawning of the adult salmon in the Luven'ga river are characterized by having a normal state of all of the fins and

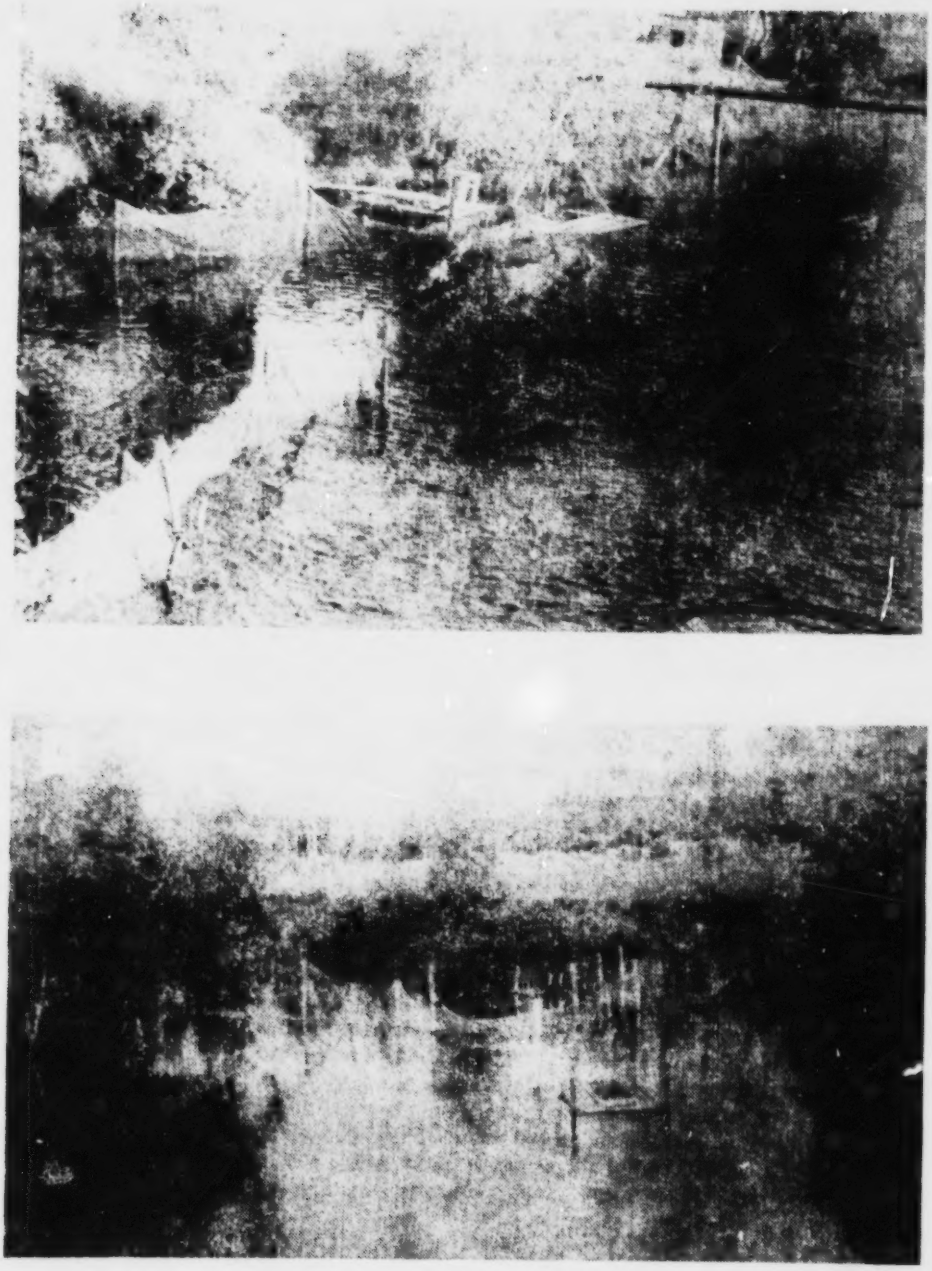

Рис.5. Рыбоучетные заграждения для молоди (а) и взрослой семги (б).

Figure 5. Fish counting weirs for juvenile (a) and adult (b) salmon.

a brilliant coloration. The hatchery-reared juveniles comprise the fish that were reared in the Kandalaksha fish hatchery from eggs of the Luven'ga river salmon, migrating downstream in the year of their release, and they were distinguished by necrotic injury to the dorsal fin, by a disruption of the integrity of the scale covering and a faded coloration. The overwintered juveniles comprise hatchery-reared juveniles which migrate to the sea a year or two after their release into the river, and they were recognized by their dorsal fine, which had already become cicatrized following the necrosis and by the brighter coloration. The hatchery and overwintered juvenile fish were also differentiated from the wild fish by the absence of the adipose fin, which was amputated at the hatchery for the identification of the reared fish. In those cases when it was difficult to assign the young salmon to one or other group on the basis of their external appearance, we collected scale samples from such fish. An analysis of the structure of the scales allowed us to identify the fish precisely (Loenko, 1983). The main part of the juvenile fish that were counted were released into the river. In the first years of this work the salmon were released directly beside the holding net. Later however, noticing that the two net walls forming the holding pen in the channel for the adult fish, below the FCW, represented a serious obstacle for the juvenile fish, we transferreed the fish that had been counted in a bucket and released them into a small backwater below the holding pen in the channel.

Some of the juvenile fish were used for age, sex, size and other types of analyses. Since, with such a methodology for selecting the samples, it was not possible to ensure a proportionality of representation of all three of the studied groups in a sample, the characteristics obtained in each sampling belonged to the whole quantity of fish of one or other group over a specific period. In other words, the statistical "weight" for the fish of each group is not their number in the sample taken for analysis but rather the number among all of the fish from which the given sample was taken. In our work we make use of the index P_{rem} - average mass of juvenile fish remaining in the river, which was determined by a calculation method according to the equation:

$$P = \frac{P_{rel} \cdot N_{rel} - P_{migr} \cdot N_{migr}}{N_{rel} - N_{migr}}$$

where P_{rel} - average mass of released juvenile fish;

P_{migr} - average mass of juvenile fish migrating at an age of 2+;

N_{rel} - number of juvenile fish released;

N_{migr} - number of migrating juvenile fish.

It is necessary to define more precisely the terms utilized by us in this study. Usually the terms "*pokatnik*" [consistently translated here as "downstream migrant"], "*serebryanka*" [consistently translated here as "silvery smolt"] and "*smolt*" [consistently translated here as "smolt" alone] are considered as synonyms (Yandovskaya et al., 1979), although this is not correct for the following reasons. The migration of the young Atlantic salmon is functionally determined and has an active character, in connection with which we, in the footsteps of I. A. Barannikova, consider as unfortunate in this case the usage of the term "*pokatnik*", which is usually used to designate passive migrants.

In the paper on "Salmonid terminology" (Allan and Ritter, 1977) the smolt is defined as "a completely silvered juvenile fish in the process of the first migration to the sea", while the "partially silvered parr" migrating downstream along the river , in the opinion of these authors, are not smolts. In several rivers, however, all or almost all of the migrating juvenile fish are not silvery smolt ["*serebryanka*"] but rather are silvery parr ["*serebristaya pestryatka*"]. This situation is found in rivers in the basins of the White Sea (Nusenbaum, 1953; Bakstansky et al., 1979; Ermolaev, 1980), the North Sea (Mills, 1964) and the Baltic Sea (Mitans, 1968), as well as in rivers of the Lake Onega basin (Smirnov, 1979; Kostylev et al., 1980). The character of the migratory behaviour of the silvery parr is indicative of their readiness for the transition into the sea (lake), in spite of the incompleteness of the silvering. On the other hand, cases are known of observations on silvery smolt that were released into a river but that did not migrate into the sea (Evropeitseva, 1957; Mitans, 1967; Wedemeyer et al., 1980). These data point to the absence of an obligatory relationship between the degree of silvering of the juvenile fish and of its migratory behaviour. "Smolt" is an ecological term (Dirin, 1982). We call those fish that are actively migrating downstream "smolts", while

juvenile fish with a corresponding exterior are called "silvery smolts". Thus, according to their appearance smolts may be both silvery smolts as well as silvery parr. Indeed, silvery smolts may be or also may not be smolts. We apply the term "*pokatnaya* " ["downstream migrant"] to juvenile fish released from the hatchery after attaining the average planned mass.

For counting the adult fish returning into the Luven'ga river an FCW of 36 millimeter netting, with a sown-in 2-bodied fyke, was set up below the FCW for the juvenile fish. The second body of the fyke was made as a fish-catching box, from which the salmon were released into the holding net in the channel. The length of the holding net comprised 50 m, the upper wall was made of 40 mm netting, the wall of the FCW served as the lower wall of the holding net. This FCW and the holding net were serviced by workers of the Kandalaksha fish hatchery. The fish were held in the channel holding net until the beginning of the fall. Then the fish in the holding net were hauled out with a drag seine and the adult fish were transferred into wooden tanks. We analyzed all of the adult salmon that got into the FCW. The excess salmon, mainly males, were subjected to complete ichthyological analysis and handed over for commercial use. Approximately 1/3 of the fish that were close to maturity were released from the holding net into the river for natural spawning. The size and age of these fish were determined prior to their release. The remaining adult fish were utilized for breeding. We conducted the ichthyological analysis on them after taking the genital products. After tagging them with individual underhanging tags, the adult fish used were released into the river.

The origin and age of the fish that died while being held in the holding net were determined. The results obtained were treated with the generally accepted statistical methods. Since in 1978 the FCW was set up prior to the release of the hatchery young but after the beginning of the migration of the wild and overwintered fish, the 1978 smolt indices were not utilized in all of the analyses. The fish returning into the Luven'ga in 1989 were analyzed after the manuscript had been sent in to the publishers, and for this reason these data are only partially utilized.

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The conditions in which our investigations were carried out are quite characteristic of all of the salmon rearing in the north of the USSR. The Kandalaksha fish hatchery is a typical White Sea salmon hatchery with contemporary equipment and a good staff. The poor quality of the water here is not exceptional but, unfortunately, is almost the norm for the majority of our hatcheries.

The Luven'ga river is one of many small rivers of the Kola peninsula, in which good conditions for habitation by salmon have been preserved. The small size of the river has allowed us to carry out a total, rather than a selective, count of the juvenile fish, which is not possible on the Kola or Umba rivers. Analyses were conducted on all of the releases of hatchery-reared third-year fish into the Luven'ga over a 10 year period (33 batches, 282 thousand downstream migrants), practically all of the juvenile fish migrating into the sea (40.2 thousand hatchery-reared fish, 8.6 thousand overwintered fish, 59.0 thousand wild fish), and all of the return (502 hatchery-reared fish and 2241 wild fish). This allowed us to compare the effectiveness of the hatchery and natural rearing of the salmon in the Luven'ga river.

Chapter 3. SURVIVAL OF THE HATCHERY-REARED JUVENILE SALMON IN THE RIVER AND IN THE SEA

3. 1. Migration of hatchery-reared juvenile fish and survival of the fish remaining in the river

Of the 41.3 thousand juvenile salmon that were released in 1978, 10454 individuals departed into the sea in the year of the release. This number comprises 25.3% of the total of juvenile fish released. For individual batches the proportion of migrating juvenile fish

ranged from 3.5 to 42.6%. In the following year 506 individual fish of the 1978 release departed into the sea (1.2% of the number released), and 76 such individuals (0.2%) left the river for the sea in 1980. In the following years no fish that had been released in 1978 were found among the salmon smolts. In all, of the 41310 fish that were released in 1978, 11070 fish, or 26.6%, departed into the sea; 31.3 thousand hatchery-reared juvenile fish (73.4%) died in the river after their release.

Of the 58.6 thousand fish that were released in 1979, 8062 fish (13.8% of the release) departed into the sea in the same year. For Batches 8 and 9 the proportion of departing fish was was 7.1 and 28.3%. In the following year 1849 overwintered fish of the 1979 release (3.2%) migrated into the sea, and one year later another 30 fish (0.05%). In the following years no smolts of the 1979 release were encountered. In all, 9941 of the 58600 juvenile fish released in 1979, or 17%, departed into the sea. More than 48 thousand fish died in the river after their release.

Of the 5.1 thousand fish released in 1980 there escaped into the sea 3055 fish (59.9% of all of the juvenile fish released; 44.4 and 74.5% of the totals in Batches 10 and 11). In the following year 399 of the overwintered fish of the 1980 release (7.8%) departed into the sea, and one year later - another 19 fish (0.4%). Older smolts of the 1980 release were not encountered by us. In all, 3474 (68.4%) fish of the 5100 fish released in 1980 departed into the sea; 1.6 thousand fish (31.9%) died in the river.

Of the 36.5 thousand juvenile fish that were released in 1981, in the same year 3614 fish departed into the sea (9.9% of all of the juvenile fish; 28.4% of Batch 12; 2.9% of Batch 13), and after one and two years - 300 and 407 fish respectively (0.8 and 1.1%). In all, 4321 (11.8%) out of the 36500 fish departed into the sea; 32 thousand fish (88.2%) died in the river.

Of the 39.4 thousand fish released in 1982, in the same year 1541, or 3.9% of the total number, migrated. In Batches 14 and 16 there were found 6 and 9 migrants, in Batch 15 - 536 individuals (11.9%), while in Batch 17 - 990 (4.0%). In the following two years there migrated into the sea 1217 and 82 fish (3.1 and 0.2%) of this same release. In all, 2840

(7.2%) out of the 3940 fish released in 1982 departed into the sea from 1982 to 1984. 36596 fish (92.8%) remained and died in the river.

22 thousand fish were released in 1983. 5399 of these fish (22.5%) migrated in the year of their release. In individual batches the proportion of departing fish ranged from 0 to 52.7%. In 1984 and 1985 there departed into the sea 340 and 315 (1.5 and 1.4%) of these fish. In all, 6055 (27.5%) of the fish released in 1983 departed into the sea, while about 18 thousand fish (72.5%) died in the river.

Out of the 19.8 thousand fish released from the hatchery in 1984 only 1927 (9.7%) departed into the sea in the same year, of which number there were 23.9% of Batch 24 and 1.5% of Batch 25; while in the following year 632 fish (3.2%) migrated, and in 1986 - 1174 fish (0.9%). Thus, 2733 (13.8%) of the juvenile fish released in 1984 migrated into the sea. The mortality in the river comprised 86.2% (17 thousand fish).

29.2 thousand fish were released in 1985, and 4159 of these departed into the sea, i.e. 14.2%. Accounted for in the year of release were 3060 fish (34%) of Batch 26, 97 fish (6.5%) of Batch 27, and 1002 fish (5.3%) of Batch 28. In the following year another 1046 fish (3.6%) departed into the sea, and 414 more fish (1.4%) in 1987. In all, 5629 (19.3%) migrated out of the 29200 fish released in 1985. 23688 fish (80.7%) died in the river.

In 1986 there were released into the river 31400 fish, of which 3545 individuals, or 11.3%, departed into the sea in the year of their release. Most probably all of the juvenile fish of Batch 29, which were released by way of the holding net set up below the FCW, departed into the sea. 1583 fish (16.9%) of Batch 30 departed into the sea, as did 206 fish, or 1%, of Batch 31. In 1987 there departed into the sea 1005 fish of the previous year's release (3.2%), and in 1988 - 75 fish (0.2%). 26775 fish (85.3%) died in the river. A total of 4625 fish (14.7%) of the juvenile salmon released in 1986 migrated into the sea.

43300 fish were released in 1987. 10637 individuals migrated into the sea (24.6% of the total number of fish released; 26.4 and 22.1% of Batches 32 and 33, respectively).

3. 1. Effect of the conditions of the release on the migration of the juvenile fish from the river

For the analysis of the effect of the conditions of the release on the migration of the juvenile fish from the river, we made use of the data on the batches of released juvenile fish, for which the proportions of the migrating fish were determined. In Table 6 are presented data on 28 releases, that are arranged according to the value of the proportion of migrating fish. The treatment of the data in the table was carried out by methods of correlation analysis and test analysis.

Correlation analysis is the most prevalent method of analysis of the interrelationship of features. The correlation analysis of the matrix of 8 features showed that out of 36 paired correlation coefficients only 4 proved to be significant. The proportion of migrating fish is correlated with the mass of the individual fish (+0.55) and with the date of the release (-0.54). The latter is correlated with the water temperature (+0.51). The distance from the point of release to the estuary is correlated with the lake factor (+0.69). The combined effect of the date of release and the mass of the fish on the proportion of migrants is higher than the effect of each of these separately. The multiple correlation coefficient of these features is +0.67.

The test method provides a second possibility of analysis (Gold'man and Chipulis, 1976). This method allows one to analyze patterns of the "If ..., then ..." type, to find "rough" relationships which would not be critical to small fluctuations of the initial parameters.

In our case we set ourselves the task of finding those parameters of the release of the juvenile fish, which determined a small or a large proportion of the migrating fish.

We will define some necessary concepts.

Feature. In the task under consideration the features are: x_1 - date of release, days; x_2 - average mass, g; x_3 - total mass, kg; x_4 - distance from estuary, km; x_5 - water temperature in river; °C; x_6 - "holding net" (release by way of holding net); x_7 - "lake" (release above one or two lakes).

Table 6

Proportion of fish migrating into the sea in batches differentiated by the conditions of release

Ordinal No.	Proportion of migrating fish, %	Date of release, days after 1. 06	Average mass, g	Total mass, kg	Distance from estuary, km	Water temperature in river, °C	Holding net	Lake	Batch No. in Table 5
1	2	3	4	5	6	7	8	9	10
1	0.1	25	18.7	84	21.3	5	1	1	14
2	1.0	56	18.7	380	14.0	15	1	0	31
3	1.5	33	18.5	231	14.0	13	0	0	25
4	2.9	45	18.5	490	23.5	14	0	2	13
5	3.5	58	12.0	12	1.3	15	0	0	6
6	4.0	52	18.0	448	14.0	13	0	0	17
7	4.9	50	18.1	221	3.9	14	0	0	21
8	5.3	50	23.3	436	14.0	16	1	0	28
9	6.1	25	18.7	187	23.5	5	0	2	15, 16
10	6.5	45	23.7	36	1.3	15	0	0	27
11	7.1	40	18.0	724	1.3	16	0	0	9
12	12.2	42	18.5	100	3.9	13	0	0	4
13	14.4	76	20.5	205	3.9	10	0	0	7
14	16.9	28	30.1	281	14.0	14	1	0	30
15	18.3	47	18.5	186	1.3	11	0	0	5
16	21.7	23	21.0	27	1.3	12	0	0	1
17	22.1	38	19.6	365	14.0	11	1	0	33
18	22.7	32	17.6	18	3.9	14	0	0	19
19	23.9	8	16.7	122	14.0	9	1	0	24
20	26.4	29	21.8	538	14.0	15	1	0	32
21	28.3	8	17.6	324	1.3	5	0	0	8
22	28.4	8	22.2	222	23.5	8	0	2	12
23	34.0	28	26.1	235	14.0	9	1	0	26
24	42.6	28	18.5	269	1.3	12	0	0	2, 3
25	44.4	16	29.8	74	23.5	11	0	2	10
26	46 5	32	17.7	18	3.9	14	0	0	20
27	52.7	23	28.3	221	14.0	11	1	0	18
28	74.5	20	29.8	78	3.9	13	0	0	11

NOTE. Batches 2 and 3 were combined, since they were released with an interval of only one day, which did not allow us to reliably distinguish the migrants of each of these batches. Batches 15 and 16 were combined, since all of the characteristics in these were similar, except for the type of tag. Batches 22 and 23 were not taken into consideration, since in these batches there were released large parr, which the experimenters resettled practically individually. Batch 29 was not analyzed , since its release was carried out below the FCW, and there are no data on the proportion of fish that migrated into the sea. In the "Holding net" column: 1 - release by way of holding net; 0 - directly into the river. In "Lake" column: 1 or 2 - release above one or two lakes; 0 - into the Lower Luven'ga river.

Object. In this task the object is the batch of juvenile fish, in which the index corresponds to the ordinal number of the batch in the left column of Table 7. Every object is characterized by a specific set of features. For example, the first batch is recorded in the following fashion:

$$P = (25,\ 18.7,\ 84,\ 21.3,\ 5,\ 1.1)$$ [10]

Class. We apply the term class to the set of objects that are characterized by a closely similar value of the proportion of migrating fish. On the basis of methods of collection of the original information, it is advisable to determine the proportion of migrating fish in a qualitative rather than a quantitative fashion: large, medium,small. We have assigned to Class K_1 (small proportion of migrating fish) the batches in which the proportion of migrants is less than 10%; this class comprises Batches 1 - 11. To Class K_2 (large proportion of migrating fish) we have assigned those batches in which this index exceeds 30%, i. e. Batches 23 - 28.

We have also defined features x_1 - x_7 in qualitative terms. On the basis of the character of the distribution of the features in the batches we have introduced the following boundary values for the features: x_1 - 35 days; x_2 - 21 g; x_3 - 233 kg; x_4 - 10 km; x_5 - 12.1°C; x_6 - 0.9; x_7 - 0.9. The values of features smaller than the boundary values are taken by us as 0, while those larger - as 1. Taking into account the accepted encoding system of the values of the features, Table 6 will appear as Table 7.

To resolve the set task it is necessary to find a set of features which differentiate the objects of Classes K_1 and K_2. Such a set is called a "test". Since the number of features is small, we carried out a complete examination of all of the possible combinations.

Feature x_1 in Class K_1 takes on values of 1 and 0, while in Class K_2 - only 0. For this reason all of the objects characterized by a value of $x_1 = 1$ may be assigned to K_1. However x_1 can not be a "test", since by its means one may distinguish only 47% of the objects included in Classes K_1 and K_2. None of the other features taken separately can be considered as "tests".

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[10] The Russian word for "Batch" is "Partiya", and hence the abbreviation "P". [Tr.]

Table 7

Encoded features of Classes K_1 and K_2.

Class	Objects	x_1	x_2	x_3	x_4	x_5	x_6	x_7
K_1	1	0	0	0	1	0	1	1
	2	1	0	1	1	1	1	0
	3	0	0	0	1	1	0	0
	4	1	0	1	1	1	0	1
	5	1	0	0	0	1	0	0
	6	1	0	1	1	1	0	0
	7	1	0	0	0	1	0	0
	8	1	1	1	1	1	1	0
	9	0	0	0	1	0	0	1
	10	1	1	0	1	1	0	0
	11	1	0	1	0	1	0	0
K_2	23	0	1	1	1	0	1	0
	24	0	0	1	0	0	0	0
	25	0	1	0	1	0	0	1
	26	0	0	0	0	1	0	0
	27	0	1	0	1	0	1	0
	28	0	1	0	0	1	0	1

In Class K_1 the combination of features x_1 and x_2 takes on the values 00, 10 and 11, while in Class K_2 - 00 and 01. Thus, x_1x_2 can not be the "test", although the application of these features allows one to distinguish the objects of Classes K_1 and K_2 in 71% of cases. The addition of feature x_3 into the combination does not change the situation. The introduction of x_4 as the third feature allows one to distinguish 100% of the objects.

The combination $x_1 = 0$, $x_2 = 0$ in Class K_1 is encountered only with $x_4 = 1$, while in Class K_2 this combination occurs only with $x_4 = 0$.

Thus the combination $x_1x_2x_4$ is an "impasse test", i. e. a not excessive set of features, distinguishing the objects of the different classes.

Further examination of the features did not reveal other "tests". Recording Table 7 in accordance with the features that make up the "test" and bringing together the same sets, we obtain Table 8.

Table 8

"Impasse test" for distinguishing the objects

Class	x_1	x_2	x_4
K_1	1	0	1
	1	0	0
	1	1	1
	0	0	1
K_2	0	1	1
	0	1	0
	0	0	0

An analysis of the "test" obtained allows one to reach the following conclusions: firstly, no single feature of those that were studied, taken separately, affects the proportion of migrating fish; secondly, such features as the total mass of the batch, the holding net and the lake, even in combination with other features, do not affect the proportion of migrating fish; thirdly, such features as the date of the release, the mass of the juvenile fish and the distance from the point of release to the estuary manifest an effect on the proportion of migrating fish only in combination with one another.

As is evident from Table 8, features x_2 and x_4 take on both of the possible values in each of the classes and only feature x_1 in Class K_2 is always equal to 0. At a substantial level the description of the "test" shows that an early release is a necessary condition for having a large proportion of migrants. In this case large fish may be released both close to the estuary as well as at a distance from the latter, while small fish produce a greater proportion of migrants only when they are released close to the estuary. A small proportion of migrants is found with a late release. In this case small fish may be released both close to the estuary and far away, while large fish - only far away. A small proportion of migrants is obtained also in the case of an early release, if small fish are released far from the estuary.

3. 3. Factors affecting the survival of the juvenile fish remaining in the river

The absolute and the relative numbers of hatchery-reared fish which migrate from the river in the following years may serve as an index of the survival of the juvenile fish that do not depart from the Luven'ga in the year of their release. While a determination of the year of the release of some or other of the fish overwintering in the river is possible, as a result of an age analysis, it was not possible to determine that they belonged to a particular batch. (Even in the fish that were tagged by amputation of the fins, the latter regenerated towards the end of the summer). For this reason the survival of the fish could be determined only according to the year and not according to the individual batch. In connection with this it is necessary to characterize the conditions of the release of the juvenile fish in each of the years. For this reason we averaged the characteristics of all of the batches in one year of release (Tables 5 and 6) taking into account the size of each batch. The obtained annual characteristics of the release conditions are presented in Table 9. Table 10 contains data on the absolute and relative numbers of overwintering hatchery-reared fish which migrated at an age of 2+, 3+ and 4+. A correlation analysis was utilized to evaluate the relationships of the values included in Tables 9 and 10.

Two cases were revealed of a significant correlation of the averaged values of the release conditions with the numbers of fish migrating into the sea in the year of release.

1. The absolute number of salmon leaving the Luven'ga at an age of 2+ decreases with increasing distance of the point of release from the estuary (-0.81).;

2. The relative numbers of fish migrating at 2+ increases with an increase in the mass of the fish released (+0.78).

The quantity and quality of the juvenile fish released determines the absolute and relative numbers of fish migrating at an age of 2+ or remaining to overwinter.

The absolute number of fish remaining in the river is directly dependent on how many juvenile fish are released (+0.98), but the greater is the average mass of the released

Table 9

Average annual weighted characteristics of the conditions of the release of juvenile salmon

Year	Released fish, thousands	Date of release, days after 1. 05	Average mass, g	Total mass, kg	Distance from estuary, km	Water temperature in river, °C	Holding net	Lake
1978	41	47	18.9	781	2.2	11.3	0	0
1979	59	30	17.9	1056	1.3	12.4	0	0
1980	5	18	29.8	149	13.4	12.3	0	0.97
1981	37	35	19.5	722	23.5	12.1	0	2
1982	39	42	18.3	714	17.5	10.0	0.11	0.62
1983	22	38	21.7	477	7.5	13.1	0.35	0
1984	20	24	17.8	356	14.0	11.7	0.37	0
1985	29	43	24.2	702	13.3	13.9	0.95	0
1986	30	46	22.2	666	14.0	14.7	0.94	0

Table 10

Migration of hatchery-reared juvenile fish and survival of those remaining in the river

Year of release	Migrated at 2+		Remained in the river			Migrated after overwintering			
	thousand fish	%*	thousand fish	%*	mass, g	at age 3+		at age 4+	
						fish	%**	fish	%**
1978	10.45	25.3	30.9	74.7	18.1	506	1.64	76	0.25
1979	8.06	13.8	50.5	86.2	17.6	1849	3.66	30	0.06
1980	3.06	61.3	1.9	38.7	28.8	399	21.00	19	1.00
1981	3.61	9.8	33.4	90.2	19.1	300	0.90	407	1.22
1982	1.54	4.0	37.5	96.0	17.9	1217	3.25	82	0.22
1983	5.40	24.5	16.6	75.5	20.6	340	2.05	315	1.90
1984	1.92	9.6	18.1	90.4	17.4	632	3.49	174	0.96
1985	4.17	14.3	24.8	85.7	23.2	1046	4.22	414	1.67
1986	1.79	6.0	28.2	94.0	21.3	1005	3.56	75	0.27

* Of the number of released fish.
** Of the number of fish remaining in the river.

downstream migrants the fewer of them remain to overwinter, both in absolute and in relative terms (-0,74 and -0.78, respectively).

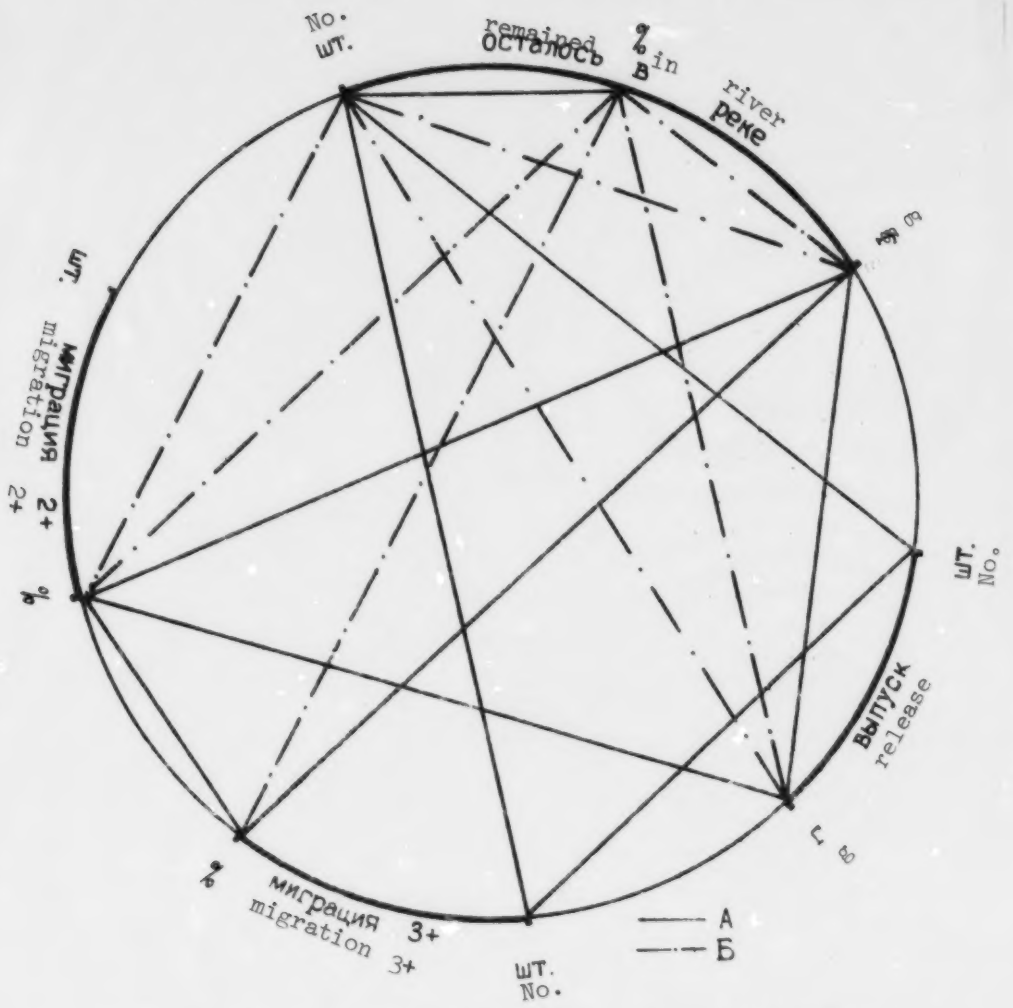

Рис.6. Связь количества и веса выпущенных покатников с абсолютным и относительным количеством молоди, мигрирующей в возрасте 2+ и 3+.

А – положительная корреляция, Б – отрицательная корреляция.

Figure 6. Relationship of the number and weight of the released downstream migrants with the absolute and relative numbers of juvenile fish migrating at an age of 2+ and 3+.

A (A) - positive correlation, B (Б) - negative correlation

The absolute number of fish migrating at an age of 3+ is positively correlated with the number of juvenile fish released (+0.68) and with the number of salmon remaining to overwinter (+0.71). The relative number of smolts migrating at an age of 3+, expressed as a percentage of the number of downstream migrants remaining in the river, is also positively correlated with the average mass of the released fish (+0.84) and with the proportion of fish

migrating at an age of 2+ (+0.86), as well as with the average mass of the juvenile fish remaining in the river to overwinter (+0.86). This index is negatively correlated with number of downstream migrants released (-0.67) and with the absolute and relative numbers of juvenile fish remaining in the river to overwinter, respectively -0.67 and -0.86.

No relationship was revealed between the numbers and survival of the fish migrating at an age of 4+ with any one of the analyzed indices. In Figure 6 is presented a correlation structure of the characteristics discussed.

3. 4. Survival of the juvenile salmon in the sea

We evaluate the survival of the hatchery-reared juvenile salmon in the sea on the basis of the numbers of adult fish coming in to the Luven'ga to spawn. The catching of the adult spawners was carried out by workers of the Kandalaksha fish hatchery.

The fish originating from the hatchery were differentiated from the fish of natural origin by their tagging: the amputated adipose fin. In all of the adult fish the age (combined, river and sea) was determined. The combined age of the fish was used for assigning a particular fish to some generation or other; on the basis of the sea age was estimated the year in which occurred the migration of the juvenile fish from the river into the sea, while the data on the river age allowed us to distinguish the hatchery-reared fish that migrated into the sea in the year of their release (at an age of 2+) and the fish that overwintered in the river (age 3+ and 4+). The calculations of the survival indices of the hatchery-reared juvenile fish in the sea are presented in Table 11.

Of the hatchery-reared juvenile fish that were released in 1978 there returned 17 adult fish to spawn in the Luven'ga in 1979 - 1982. If one refers this number to the number of juvenile fish released, then the survival rate in the sea comprises 0.04%, while if it is referred to the number of juvenile fish that migrated into the sea, then the survival comprises 0.15%. The analysis of the age of the adult fish showed that 16 out of the 17 fish

Table 11.

Survival of hatchery-reared juvenile fish released into the river

Initial group	Number, individuals	Returned, individuals	Survival, %
1	2	3	4
1978, of the 1975 generation			
Total released	41310	17	0.04
Migrated at 2+	10454	1	0.01
Remained to overwinter	30856	16	0.05
Migrated at 3+	506	11	2.17
Migrated at 4+	76	5	6.58
Migrated after overwintering	582	16	2.75
Total migrating	11036	17	0.15
1979, of the 1976 generation			
Total released	58600	9	0.02
Migrated at 2+	8062	2	0.02
Remained to overwinter	50538	7	0.01
Migrated at 3+	1849	7	0.38
Migrated at 4+	30	0	0
Migrated after overwintering	1879	7	0.37
Total migrating	9941	9	0.09
1980, of the 1977 generation			
Total released	5100	22	0.43
Migrated at 2+	3055	0	0
Remained to overwinter	2045	22	1.08
Migrated at 3+	399	18	4.51
Migrated at 4+	19	4	21.05
Migrated after overwintering	418	22	5.26
Total migrating	3473	22	0.63
1981, of the 1978 generation			
Total released	36500	37	0.10
Migrated at 2+	3614	0	0
Remained to overwinter	32886	37	0.11
Migrated at 3+	300	28	9.33
Migrated at 4+	407	9	2.21
Migrated after overwintering	707	37	5.23
Total migrating	4321	37	0.86
1982, of the 1979 generation			
Total released	39400	44	0.11
Migrated at 2+	1541	0	0
Remained to overwinter	37859	44	0.12
Migrated at 3+	1217	36	2.96
Migrated at 4+	82	8	9.76
Migrated after overwintering	1299	44	3.39
Total migrating	2840	44	1.55

Continuation of Table 11.

Initial group	Number, individuals	Returned, individuals	Survival, %
1	2	3	4
1983, of the 1980 generation			
Total released	24020	44	0.18
Migrated at 2+	5399	16	0.30
Remained to overwinter	18621	28	0.15
Migrated at 3+	340	14	4.12
Migrated at 4+	315	14	4.44
Migrated after overwintering	655	28	4.27
Total migrating	6054	44	0.73
1984, of the 1981 generation			
Total released	19800	59	0.30
Migrated at 2+	1927	4	0.21
Remained to overwinter	17873	55*	0.31
Migrated at 3+	632	52	8.23
Migrated at 4+	174	2	1.15
Migrated after overwintering	806	55	6.82
Total migrating	2733	59*	2.16
1985, of the 1982 generation			
Total released	29000	52	0.18
Migrated at 2+	4159	32	0.77
Remained to overwinter	24841	20	0.08
Migrated at 3+	1046	14	1.34
Migrated at 4+	414	6	1.45
Migrated after overwintering	1460	20	1.37
Total migrating	5619	52	0.93
1986, of the 1983 generation			
Total released	31400	53	0.17
Migrated at 2+	3545	6	0.17
Remained to overwinter	27885	47	0.17
Migrated at 3+	1005	43	4.28
Migrated at 4+	75	4	5.33
Migrated after overwintering	1080	47	4.35
Total migrating	4625	53	1.15

* Fish returned at age of 5+ 1+.

overwintered in the river after their release (11 fish - for 1 year, 5 fish - for 2 years). It is possible that the fish which migrated into the sea at an age of 2+ also overwintered in the river, since in 1977 there were released into the Luven'ga 62 thousand hatchery-reared

juvenile fish of age 1+, i. e. fish of the same generation as the third year fish that were released in 1978. However, even if it is accepted that these fish, with a river age of 2+, migrated into the sea in the year of their release, then the rate of survival in the sea of the juvenile fish of this group comprises 1/10450 (0.01%). The rate of survival of the over-wintered fish is considerably greater: 2.2% for the fish that overwintered 1 year, and 6.6% for those overwintering 2 years. If one refers these 16 fish to the number of juvenile fish that did not depart into the sea in the year of their release, then the survival rate of this group after release (in the river and the sea) comprises 0.05%.

From the downstream migrants of the 1979 release, at an age of 2+, 9 fish returned to spawn in 1980 - 1983. 7 of these, having a river age of 3+, spent no less than 1 year after their release in the river. The 2 specimens whose river age was 2+ could have been third-year fish which migrated into the sea in the year of their release, or else second-year fish, 65 thousand of which were released into the Luven'ga in 1978. In the latter case these fish stayed in the river for 1 year after their release. In order not to complicate the situation, we consider them as having been released in 1979, although, if we make such an assumption, then the survival rate of the downstream migrants in this year of release will be exaggerated.

22 of the fish released in 1980 returned in 1981-1984. All of these fish remained in the river for one (18 fish) or two (4 fish) winters. There were no returning fish with a river age of 2+. In 1979 no second-year salmon were released in the Luven'ga, and therefore the absence among the returning fish of individuals of the 1977 generation corroborates the supposition that in the preceding years the adult fish with such a river age were the return of overwintering fish that had been released at an age of 1+.

37 fish of the 1981 release returned in 1983-1985. 28 of these had remained in the river for 1 winter after their release, while 9 had stayed for 2 winters.

The 1982 release produced a return of 44 adult fish in 1984-1987; 36 of these overwintered once in the river, while 8 overwintered twice.

Of the downstream migrants that were released in 1983 there returned 44 adult salmon. The river age of these fish comprised 2, 3 and 4 years. In the preceding year there

had been no releases of juvenile fish at an age of 1+, and therefore the salmon with a river age of 2+ may be considered as a return of the juvenile fish that migrated into the sea in the year of their release. 16 such fish returned in 1984. Of the juvenile fish that had wintered in the river once and twice there returned 14 adult fish, in each case.

The 1984 release produced a return of 59 fish in 1985-1988. Of the juvenile fish that migrated into the sea in the year of their release, 4 returned. The rest of the return comprised salmon that had overwintered in the Luven'ga. Among the adult fish of this release was found a male which had remained in the river for 3 years following the release; 2 salmon had overwintered in the river for 2 years, and 52 fish had stayed in the river for one year after their release.

52 of the salmon that had been released in 1985 returned in 1986-1989.

In 1987 - 1989 there returned into the Luven'ga 53 salmon from the 1986 release. A continued return of salmon from this release is expected in 1990-1991.

46 fish out of the 10640 hatchery-reared juvenile fish that migrated into the sea in 1987 at an age of 2+ returned in 1988, i. e. 0.43%. The main return of this release will take place in the following years.

In all, during the period of observation 50567 fish of hatchery origin migrated into the sea. The return from this number comprised 427 fish, or 0.84%.

In order to evaluate the effect of the release conditions on the survival of the hatchery-reared salmon in the sea, a correlation analysis was carried out. The characteristics of the release conditions were taken from Table 9. Serving as the survival indices were the following values: the survival rate based on all of the juvenile fish released, and the survival rate based on the juvenile fish migrating at 2+, 3+ and 4+.

These indices are included in Table 11. The later releases, the return from which is still incomplete, have not been analyzed.

The following indices are significantly correlated: the survival rate of all of the released juvenile fish is decreased with an increase in their numbers (–0.94) and total mass (–0.95).

The survival rate of the juvenile fish that migrated in the year of their release is reliably correlated with the proportion of fish that were released by way of the holding net. In the analysis of data obtained over a 7 year period the correlation coefficient comprised 0.99. The survival in the sea of the juvenile fish that migrated from the river at an age of 3+ and 4+ is not reliably correlated with the release conditions.

As was shown in the preceding chapter, the survival of the juvenile fish in the river depends on the numbers of juvenile fish released (see Figure 4 [11]). From Figure 7 it is evident that an increase in the number of of juvenile fish released decreases their survival rate in the sea, but this relationship is manifested with varying intensity in the different groups.

During these same years 56355 wild smolt migrated into the sea, of which number 2001 salmon (3.55%) returned. Thus, the survival rate in the sea of the hatchery-reared juvenile fish that migrated from the river was only 1/4 of the survival rate of the wild fish. The data on the survival rate of the wild smolts are presented in Table 12. *

In the comparison of the survival rate in the sea of the hatchery-reared and the wild fish of these generations, the return of which was already fully completed (Table 13), it is evident that the survival rate of the wild fish is 5 times better than that of the hatchery-reared fish. This difference is determined in the first instance b by the low survival rate of the hatchery-reared juvenile fish that migrated into the sea at 2+ (Table 14). In the wild smolts each following age group produces twice as great a return as the preceding group. In the hatchery-reared fish the return from the 2+ juveniles is 1/40 of that from the 3+ juvenile fish. It is noteworthy that the survival rate in the sea of the hatchery-reared juvenile fish that overwintered in the river does not differ from this index in the wild fish of the same age,

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* The results obtained for the wild salmon of the Luven'ga river approximate the results obtained on the Por'ya river - 3.77% (Yakovenko et al., 1981).

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[11] Sic. However this reference was probably intended to Figure 6, or possibly to Figure 7. [Tr.]

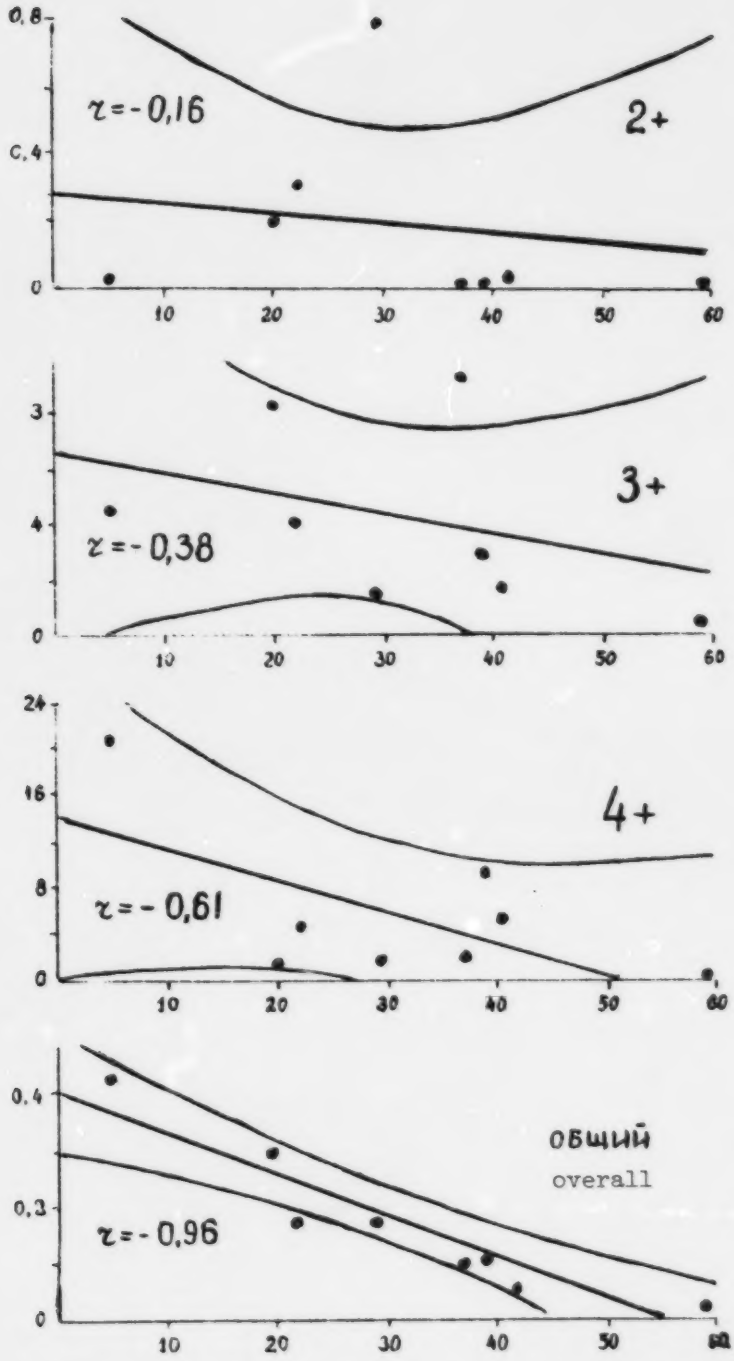

Рис.7. Связь количества выпущенной молоди с возвратом производителей.

Линия регрессии с 95%-м доверительным интервалом, r - коэффициент корреляции. По вертикали - возврат от количества мигрантов данной группы, %, по горизонтали - количество выпущенных рыб, тыс.шт.

Figure 7. Relationship between numbers of juvenile fish released and the return of the spawners.

Regression line with 95% confidence interval; r - correlation coefficient. Along the vertical - return of the number of migrants of a given group, %; along the horizontal - number of fish released, in thousands.

Table 12

Survival of wild smolts in the sea

Year of migration	Age of smolt, years	Number of smolts, fish.	Return, fish (%)
1	2	3	4
		1975 generation	
1978	2+	290	2 (0.69)
1979	3+	5167	72 (1.39)
1980	4+	1335	35 (2.62)
1981	5+	0	2
Total		6792	111 (1.63)
		1976 generation	
1979	2+	359	1 (0.28)
1980	3+	3743	40 (1.07)
1981	4+	185	36 (19.46)
1982	5+	0	1
Total		4287	78 (1.82)
		1977 generation	
1980	2+	532	0
1981	3+	3601	74 (2.05)
1982	4+	3532	173 (4.90)
1983	5+	99	2 (2.02)
Total		7764	249 (3.21)
		1978 generation	
1981	2+	121	0
1982	3+	2989	103 (3.45)
1983	4+	1086	44 (4.05)
Total		4196	147 (3.50)
		1979 generation	
1982	2+	250	2 (0.80)
1983	3+	2612	106 (4.06)
1984	4+	316	26 (8.23)
1985	5+	6	0
Total		3184	134 (4.21)
		1980 generation	
1983	2+	355	16 (4.51)
1984	3+	2222	127 (5.72)
1985	4+	110	24 (21.82)
1986	5+	126	1 (0.79)
Total		2813	168 (5.97)

Table 12 continued

Year of migration	Age of smolt, years	Number of smolts, fish.	Return, fish (%)
1	2	3	4
		1981 generation	
1984	2+	88	14 (15.91)
1985	3+	3666	160 (4.36)
1986	4+	5192	19 (0.37)
1987	5+	161	5 (3.11)
Total		9107	198 (2.17)
		1982 generation	
1985	2+	690	36 (5.22)
1986	3+	10245	96 (0.94)
1987	4+	4906	67 (1.37) **
1988	5+	112 ***	7 (6.25) **
Total		15953	
		1983 generation	
1986	2+	85	5 (5.88)
1987	3+	2226	122 (5.48) **
		1984 generation	
1987	2+	60	18 (30.00) **

* In parentheses - return (%) from the number of smolts of a given group.
** Return not completed.
*** In 1988 we did not conduct a count of the smolts, and for this reason the number of smolts at age 5+ was calculated on the basis of the many-year data on the age structure of the salmon smolts in the Luven'ga river (see Chapter 4. 1).

Table 13

Survival rates in the sea of the same generations, %

Generation	Hatchery-reared	Wild
1975	0.15 (17 / 11036)*	1.63 (111 / 6792)
1976	0.09 (9 / 9941)	1.82 (78 / 4287)
1977	0.63 (22 / 3473)	3.21 (249 / 7764)
1978	0.86 (37 / 4321)	3.50 (147 / 4196)
1979	1.55 (44 / 2840)	4.21 (134 / 3184)
1980	0.73 (44 / 6054)	5.97 (168 / 2813)
1981	2.16 (59 / 2733)	2.17 (198 / 9107)
Many-year average	0.57 ± 0.04 (232 / 40398)	2.84 ± 0.09 (1077 / 37912)

* In parentheses - the numbers of fish that returned / migrated into the sea.

Table 14

Survival rates in the sea, %, of juvenile fish of the 1975 - 1980 generations

Age of juvenile fish	Hatchery-reared	Wild
2+	0.06 ±0.01 (19 / 32125)*	1.10 ± 0.24 (21 / 1907)
3+	2.47 ± 0.23 (114 / 4611)	2.57 ± 0.11 (522 / 20334)
4+	4.31 ± 0.67 (40 / 929)	5.12 ± 0.27 (336 / 6564)

* In parentheses - the numbers of fish that returned / migrated into the sea.

the survival rate in the sea of the wild and the hatchery-reared juvenile fish which migrated from the river at an age of 2+ differs by a factor of almost 20 times (Table 14).

* * *

During the period from 1978 to 1985 there were released into the Luven'ga 253.7 thousand downstream migrant salmon. The return from these juvenile fish has already been completed and comprised 284 fish. The survival rate from release to return is 0.1%; 253.4 thousand hatchery-reared fish died in the river and the sea. Of the fish that died, 207.7 thousand (82%) died in the river and 45.7 thousand (18%) died in the sea. For the different generations the ratio of the numbers of fish dying in the sea changes (Figure 8) but, with the exception of the fish that were released in 1980, the principal losses of the production of the fish hatchery occur in the river. In spite of the elimination of 4/5 of the downstream migrants in the river, the juvenile fish that migrated into the sea in the year of their release survive much worse there than do the wild fish.

The situation is dismal but not hopeless. In the first place, the hatchery-reared juvenile fish that survived after overwintering in the river produce a return that is comparable with the return of the wild juvenile fish. Secondly, the detected influence of the release conditions on the survival rate of the salmon in the river and in the sea allow us to hope for an improvement of the survival rate of the released juvenile fish with the use of rational release biotechniques.

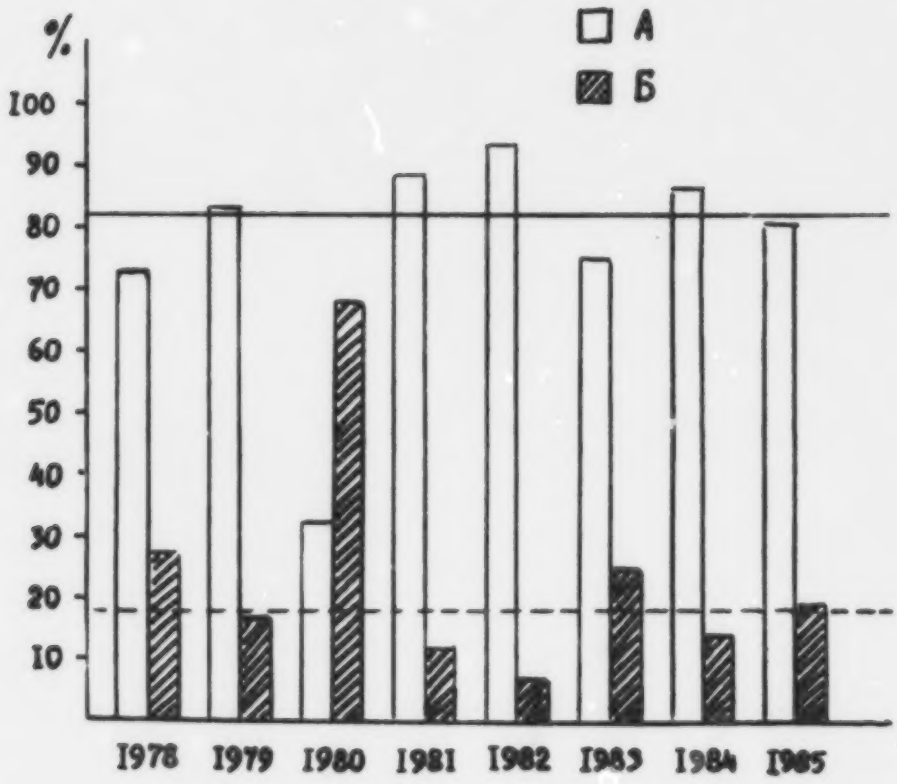

Рис.8. Гибель выпущенных рыб в реке и море.

По вертикали – смертность, процент от общего количества погибших рыб в реке (А) и море (Б). По горизонтали – год выпуска. Сплошная линия – средняя многолетняя доля рыб, погибших в реке; пунктирная – в море.

Figure 8. Mortality of released fish in the river and in the sea.

Along the vertical - mortality, as percentage of the total number of the fish that died in the river (A) and in the sea (B - Б). Along the horizontal - year of release. Continuous line - average many-year proportion of fish dying in the river; dashed line - in the sea.

Chapter 4. COMPARISON OF CHARACTERISTICS OF THE HATCHERY-REARED AND WILD JUVENILE FISH

4. 1. Age structure

The fish of different origin are differentiated by their age structure. In the hatchery-reared fish this structure is the simplest. All of the fish have an age of 2+. The overwintered fish are represented by ages 3+ and 4+. The age of 3+ is dominant, comprising 67 - 97% of the fish of a given group (Table 15). The average age of the overwintered fish is between 3.0 and 3.3 years, and the average over the 9 year period was equal to 3.2 years.

In the wild smolts the age structure is most complex. The fish are represented by 4 age groups. Individuals at an age of 3+ are dominant (65%), and in second place is the 4+ group (30%). In 1967 [12], however, fish at an age of 4+ predominated (Table 15). Rarest of all and not every year are encountered fish at an age of 5+. In spite of the differences in the age structure of the wild and the overwintered fish, their average age is similar - 3.3 and 3.2 years. In Table 16 are presented data on the distribution by age of the wild and the overwintered smolts of seven generations. With this calculation variant the 3+ group is also dominant, though the 4+ age is found to be modal among the wild fish of the 1981 generation and among the overwintered fish of the 1978 generation. The values for the average age obtained in both calculation variants (according to the years of migration and according to generations) are closely similar. From each generation of wild fish two thirds migrate at an age of 3+, and a quarter at 4+. The variability in the proportion of smolts migrating at 4+ was found to be 3 times greater than at 3+ (coefficients of variation 92% and 29%, respectively).

In Table 17 we have gathered together the literature data on the age and length of the smolts of the Atlantic salmon from different rivers. From this table it is evident that the

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[12] Sic. Should be 1987. [Tr.]

Table 15

Age compoeition (%) and average age (years) of smolts that are migrating in the same year

Year of migration	Wild					Overwintered		
	age group				average age	age group		average age
	2+	3+	4+	5+		3+	4+	
1979	4.2	82.0	13.8	0	3.1	97.1	2.9	3.0
1980	9.8	68.5	21.7	0	3.1	96.1	3.9	3.0
1981	3.1	92.2	4.7	0	3.0	93.0	7.0	3.1
1982	3.7	44.1	52.2	0	3.5	94.0	6.0	3.3
1983	8.6	62.8	26.2	2.4	3.2	74.9	25.1	3.2
1984	3.4	84.6	12.0	0	3.1	80.6	19.4	3.2
1985	15.4	82.0	2.5	0.1	2.9	66.7	33.3	3.3
1986	0.5	65.5	33.2	0.8	3.3	85.7	14.3	3.1
1987	0.8	30.3	66.7	2.2	3.7	70.8	29.2	3.3
Many-year mean abeolute	4.3	65.0	30.0	0.7	3.3	82.6	17.4	3.2

Table 16

Age composition (%) and average age (years) of smolts of the same generation

Year of migration	Wild					Overwintered		
	age group				average age	age group		average age
	2+	3+	4+	5+		3+	4+	
1976	4.3	76.1	19.6	0	3.2	86.9	13.1	3.1
1977	8.4	87.3	4.3	0	3.0	98.4	1.6	3.0
1978	6.9	46.3	45.5	1.3	3.4	95.5	4.5	3.0
1979	2.9	71.2	25.9	0	3.2	42.4	57.6	3.6
1980	7.9	82.0	9.9	0.2	3.0	93.7	6.3	3.1
1981	12.6	79.0	3.9	4.5	3.0	51.9	48.1	3.5
1982	1.0	40.3	57.0	1.7	3.6	78.4	21.6	3.2

salmon smolts of the Luven'ga river are older than the smolts of other White Sea rivers. Kuz'min and Smirnov (1982), who studied the smolts of the Luven'ga salmon in 1964, determined that the average age of these fish was 3.2 years. Smolts from the rivers of the Barents Sea are older than the Luven'ga smolts.

In Table 18 is presented the age structure of adult salmon of different origin. 10 of the 12 possible combinations of river and sea age were encountered among the 2.5 thousand fish. Fish at an age of 5.2 and 5.3 were not found in our material. Significant

Table 17

Age and size of smolts of the Atlantic salmon

River	Age, years	Length, cm
1	2	3
USSR		
White Sea		
Luven'ga [1]	3.30 / 2+ - 5+	13.2 / 10.9 - 14.4
Zimnyaya Zolotitsa [2]	2+ - 3+	11.3 - 13.5
Soyana [2]	2+ - 4+	12.3 - 14.7
Pulon'ga [3]	3.15 / 1+ - 5+	11.9 / 10.0 - 15.0
Chavan'ga [3]	3.08 / 2+ - 5+	10.3 / 7.8 - 12.8
Varzuga [3]	2.91 / 1+ - 5+	10.3 / 8.1 - 12.7
Varzuga [4]	2.84 / 2+ - 3+	10.2 / 7.2 - 13.2
Por'ya [3]	3.22 / 2+ - 5+	12.7 / 9.0 - 15.7
Umba [4]	2.45 / 2+ - 4+	11.5 / 7.5 - 18.0
Umba [5]	2.72 / 2+ - 3+	12.9 ± 0.2
Pon'goma [6]	2.48 / 2+ - 4+	13.3 / 9.5 - 16.5
Chapoma [4]	2.63 / 1+ - 4+	11.7 / 3.0 - 15.2
Strel'na [4]	2.38 / 2+ - 3+	10.9 / 9.0 - 13.5
Pyalitsa [7]	2.78 / 2+ - 4+	12.4 / 11.7 - 15.0
Barents Sea		
Sidorovka [3]	4.20 / 3+ - 6+	15.5 / 12.1 - 21.5
Varzina [3]	4.09 / 3+ - 6+	14.6 / 12.6 - 19.1
Rynda [1]	4.02 / 2+ - 5+	14.7 / 9.1 - 15.9
Kedva [8]	3.43 / 2+ - 5+	15.2
Lake Onega		
Shuya [6]	2.11	13.7 / 11.0 - 18.0
Lake Ladoga		
Khiitola [6]	2.26	15.3 / 11.9 - 18.4
Scotland		
North Esk [9]	-	13.5 / 9.5 - 20.0
Norway		
Imsa [10]	-	16.3 ± 1.2
Beiarel'va* [11]	5.20 ± 0.20	13.0 ± 0.4
Soltdasel'va* [11]	4.80 ± 0.20	12.7 ± 0.2
Strinsel'va* [11]	3.40 ± 0.10	12.1 ± 0.2
Ireland		
Berimul* [12]	2.00 / 1+ - 3+	14.0 ± 0.1
Finland		
Simojoki [13]	2+ - 4+	15.7 ± 0.2

* The spelling of these Norwegian and Irish rivers here is a back-transliteration from the Russian version. [Tr.]

Table 17 continued

River	Age, years	Length, cm
1	2	3
Canada		
Restigouche	-	14.2
Sabbies	2.38	12.7 ± 0.8
Bluehill	4.80	20.2
Wings	4.00	16.4
Western Arm Brook	3.86 ± 0.04	17.2 ± 0.1
Codroy	2.63 / 2+ - 5+	

NOTE: 1 - our own data; 2 - Sakhonchik, 1971; 3 - Kuz'min and Smirnov, 1982; 4 - Mel'nikova, 1970; 5 - Kazakov and Semenova, 1986; 6 - Ermolaev, 1988; 7 - Kazakov, 1987; 8 - Antonova, 1983; 9 - Sheares, 1965; 10- Hansen et al., 1984; 11 - Jensen and Johnsen, 1986; 12 - Piggins and Mills, 1985; 13 - Virtanen, 1988; 14 - Pepper, 1982; 15 - Riddell and Leggett, 1981; 16 - Hitchings, 1986; 17 - Chadwick et al., 1978; 18 - Murray, 1968.

Table 18

Age structure of wild and hatchery-reared spawners of the Luven'ga river salmon, %

River age	Sea age, years			
	1+	2+	3+	4+
2+	4.2 / 3 - 5 *	0.8 / 0 - 2 *	0 / 0 - 0	5.0 / 4 - 7 *
	28.9 / 23 - 35	3.7 / 2 - 7	0.4 / 0 - 2	33.0 / 27 - 39
3+	50.2 / 47 - 53	13.1 / 11 - 15	0.1 / 0 - 1	63.4 / 60 - 66
	45.4 / 39 - 51	9.5 / 6 - 14	0.8 / 0 - 4	55.8 / 50 - 62
4+	25.3 / 22 - 28 *	5.4 / 5 - 7 *	0 / 0 - 0	30.7 / 28 - 34 *
	9.3 / 6 - 13	1.4 / 1 - 4	0.2 / 0 - 1	11.0 / 7 - 15
5+	0.8 / 0 - 2	0 / 0 - 0	0 / 0 - 0	0.8 / 0 - 2
	0.2 / 0 - 2	0 / 0 - 0	0 / 0 - 1	0.2 / 0 - 2
Σ	80.6 / 78 - 83	19.3 / 17 - 22	0.1 / 0 - 1	
	83.9 / 79 - 89	14.7 / 10 - 20	1.4 / 0 - 5	

NOTE. Average value / 95% confidence interval. Above the line - 2241 wild fish; below the line - 484 hatchery-reared fish.

* Significance of difference wild / hatchery > 0.95

Table 19

Average age of spawners of the Luven'ga river salmon, years

Age	Wild	Hatchery-reared	Δ
Combined	4.46 ± 0.07	3.94 ± 0.02	0.52
River	3.26 ± 0.06	2.78 ± 0.06	0.48
Sea	1.20 ± 0.04	1.16 ± 0.04	0.04

differences in the frequency of occurrence of salmon from hatchery and natural reproduction were found in four age groups: there were more hatchery fish in groups 2.1 and 2.2, and more wild fish in groups 4.1 and 4.2. These differences are manifested in the comparison of the river and the sea age of the spawners. Thus, the hatchery fish are dominant in the younger age groups , while the wild fish dominate in the older age groups. The calculation of the average age of the spawners showed that the wild fish are half a year older than the hatchery fish (Table 19), mainly because of the difference in the river age, while the differences in the sea age are insignificant.

4. 2. Sex structure

The proportion of males and females was the same in the downstream migrants that were released from the hatchery. There were few dwarf males - 10%. Among the hatchery-reared juvenile fish that migrated in the year of their release the ratio of the sexes was the same. We did not find dwarf males among these fish. In the overwintering smolts the males comprised from 33 to 64% in different years. The many-year proportion of males was 51% (Figure 9) though their predominance was not significant. If one analyzes the overwintering fish according to the age groups, then among the 3+ smolts the proportion of males is significantly greater than that of the females, while in the 4+ smolts the differences were not significant (Table 20).

Among the wild smolts females predominated (52 - 73%) during 8 out of the 9 years. Only in 1987 did the females comprise 48%. Over the 9 years of observation the proportion

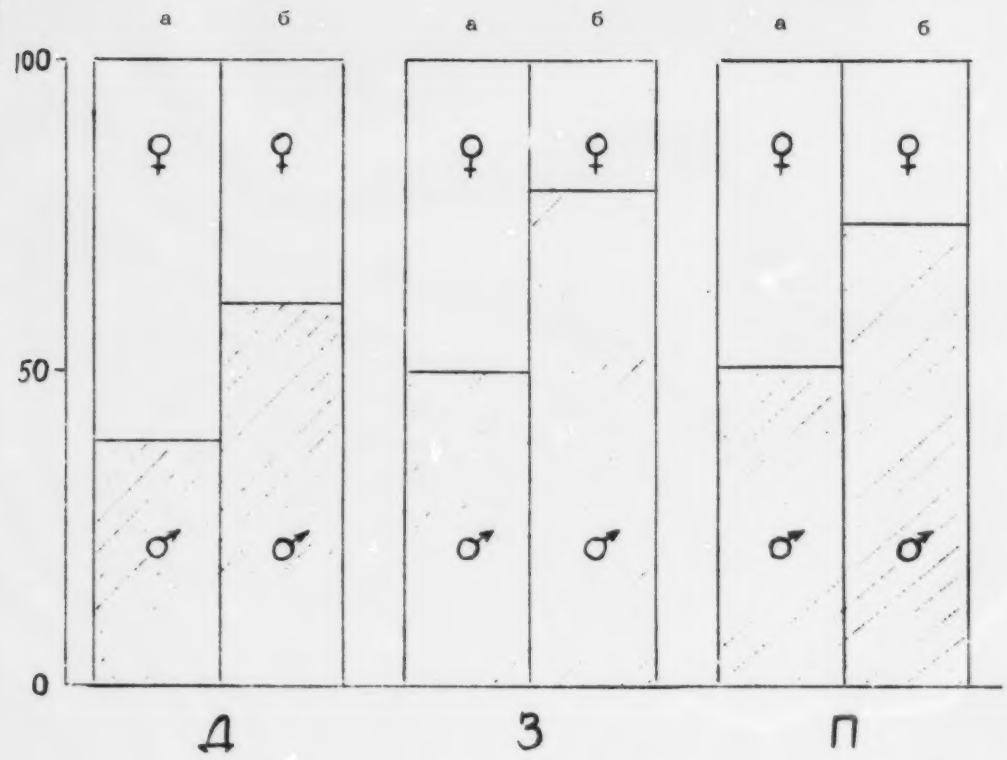

Рис.9. Соотношение полов, %, среди мигрирующей молоди (а) и взрослых рыб (б). Д – дикие, З – заводские, П – перезимовавшие.

Figure 9. Sex ratio, %, among migrating juvenile fish (a - a) and adult fish (б - b).

Д - D - wild, З - Z - hatchery-reared, П - P - overwintered.

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of females comprised 61%. The significance of the deviations from the 50:50 ratio, calculated on the basis of of the χ^2 criterion, is greater than 0.999. According to the individual age groups a higher proportion of females is also noted (Table 20). The wild smolts differ significantly ($p > 0.999$) from the hatchery-reared and overwintered juvenile fish on the basis of the sex ratio (Figure 9).

The sex ratio of the wild smolts in the Luven'ga river is the same as of the smolts of other rivers, where there are found 1.2 - 3.8 females per 1 male (Mel'nikova, 1970; Chadwic et al., 1978; Martynov, 1983, and others). This is explained by the fact that some of the male parr do not turn into smolt but mature, becoming dwarf males. However among the adult salmon returning into the Luven'ga there are more males than females. Males of the wild

Table 20

Ratio of males and females, as %, among the juvenile salmon

Age, years	Males	Females	p*
	Hatchery-reared fish in the hatchery		
2+	49	51	<0.95
	Hatchery-reared fish in the river		
2+	50	50	<0.95
	Overwintered fish		
3+	52	48	>0.99
4+	48	52	<0.95
	Wild fish		
2+	48	52	<0.95
3+	38	62	>0.999
4+	41	59	>0.999
5+	30	70	>0.95

Significance of differences from the 50:50 ratio.

salmon predominated in the return of 10 years out of 11. Only in 1984 did their proportion drop down to 39%, , comprising from 50 to 82% in the other years (Table 21), and over the whole period - 61%. Among the return from the hatchery-reared juvenile fish (migrating into the sea in the year of release at an age of 2+) there were 79% males, while in the return of the overwintered fish there were 74% males (Tables 22 and 23); it is true that in 1982 there were more females (57%) in the return of the overwintered fish.

Thus, while more females than males (or just as many) migrate into the sea, conversely more males return (Figure 9). Consequently, the males survive better than the females in the sea. The cause of this may be the greater duration of the marine period of life of the females (Table 24), because of which their probability of dying in the sea is greater.

Table 21

Sex and age composition of wild salmon returning into the Luven'ga river over 11 years, fish.

Age, years	1979			1980			1981			1982			1983			1984		
	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ
2+ 1+	2	0	2	1	0	1	0	0	0	0	0	0	0	0	0	11	1	12
2+ 2+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
3+ 1+	37	2	39	71	1	72	5	4	9	38	0	38	55	10	65	46	44	90
3+ 2+	2	23	25	8	52	60	0	0	0	0	31	31	0	36	36	5	33	38
3+ 3+	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0
4+ 1+	12	2	14	36	1	37	3	1	4	19	0	19	145	9	154	14	23	37
4+ 2+	2	7	9	0	14	14	0	0	0	1	30	31	0	17	17	0	19	19
5+ 1+	0	0	0	0	0	0	0	0	0	2	0	2	1	0	1	2	0	2
Total	55	34	89	118	68	186	8	5	13	60	61	121	201	72	273	78	122	200

Table 21 continued

Age, years	1985			1986			1987			1988			1989			Total		
	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ
2+ 1+	7	5	12	32	2	34	0	1	1	9	5	14	7	12	19	69	26	95
2+ 2+	0	4	4	0	2	2	0	2	2	0	4	4	1	3	4	1	17	18
3+ 1+	70	36	106	135	11	146	49	9	58	70	37	107	303	192	395	779	346	1125
3+ 2+	0	16	16	1	20	21	2	12	14	2	35	37	2	13	15	22	271	293
3+ 3+	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	3	0	3
4+ 1+	12	11	23	20	2	22	8	2	10	57	40	97	89	62	151	415	153	568
4+ 2+	0	7	7	0	3	3	1	1	2	0	9	9	0	10	10	4	117	121
5+ 1+	0	0	0	0	0	0	1	0	1	5	0	5	2	5	7	13	5	18
Total	89	79	168	188	40	228	61	27	88	143	130	273	305	297	602	1306	935	2231

Table 22

Sex and age composition of hatchery-reared salmon returning into the Luven'ga river over 11 years, fish.

Age, years	1979			1980			1981			1982			1983			1984		
	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ
2+ 1+	0	0	0	2	0	2	0	0	0	0	0	0	0	0	0	14	1	15
2+ 2+	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
2+ 3+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	1	0	1	2	1	3	0	0	0	0	0	0	0	0	0	14	1	15

Table 22 continued

Age, years	1985			1986			1987			1988			1989			Total		
	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ
2+ 1+	2	0	2	28	0	28	4	0	4	34	12	46	34	9	43	118	22	140
2+ 2+	0	0	0	0	2	2	0	4	4	0	1	1	0	9	9	1	17	18
2+ 3+	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	0	2	2
Total	2	0	2	28	3	31	4	4	8	34	13	47	34	19	53	119	41	160

Table 23

Sex and age composition of overwintered salmon returning into the Luven'ga river over 11 years, fish.

Age, years	1979			1980			1981			1982			1983			1984		
	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ
3+ 1+	5	0	5	9	0	9	1	0	1	10	0	10	17	3	20	23	2	25
3+ 2+	0	0	0	1	0	1	0	0	0	0	5	5	0	7	7	3	5	8
3+ 3+	0	0	0	0	0	0	0	0	0	0	2	2	0	1	1	0	1	1
4+ 1+	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4	7	0	7
4+ 2+	0	0	0	0	0	0	0	0	0	0	5	5	0	0	0	0	0	0
4+ 3+	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
5+ 1+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	5	0	5	10	0	10	1	0	1	10	13	23	21	11	32	33	8	41

Table 23 continued

Age, years	1985			1986			1987			1988			1989			Total		
	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ	♂	♀	Σ
3+ 1+	11	2	13	49	1	50	8	2	10	24	12	36	30	11	41	187	33	220
3+ 2+	0	11	11	0	1	1	0	2	2	0	4	4	0	7	7	4	42	46
3+ 3+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4
4+ 1+	8	0	8	14	0	14	2	0	2	5	1	6	3	1	4	43	2	45
4+ 2+	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	7	7
4+ 3+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
5+ 1+	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	1
Total	19	15	34	63	2	65	10	4	14	30	17	47	33	19	52	235	89	324

Table 24

Sea age of the Luven'ga river salmon, years

Group	Males	Females
Wild	1.03 ± 0.01	1.59 ± 0.02
Hatchery-reared	1.01 ± 0.01	1.32 ± 0.12
Overwintered	1.02 ± 0.01	1.74 ± 0.07

4. 2. Size characteristics

The size indices of the migrating juvenile fish of different origin, obtained by a statistical weighting of the data of nine years of observations, are presented in Table 25. The hatchery-reared juvenile fish were found to be larger than the wild fish and the overwintered fish, although they were younger by 1.2 - 1.3 years. Judging by the average yearly data (Table 26), these differences are not manifested every year. Thus, in 1979 and 1983 the wild juvenile fish were the largest, while in 1981 the overwintered fish were the largest. For all that, however, in the other six years the hatchery-reared fish were the largest.

Table 25

Size indices of migrants over the whole period of observations

Group	Length, cm	Mass, g	Numbers, fish
Hatchery-reared	14.1 ± 0.1	26.3 ± 0.1	40190
Overwintered	13.3 ± 0.1	22.0 ± 0.1	8626
Wild	13.2 ± 0.1	22.1 ± 0.1	59036

In each of the groups under comparison the variability of the average yearly values is high, which may be caused by a change in the age or sex structure. We will attempt to evaluate the effect of these factors.

Table 26.

Average yearly values of the length and the mass of migrants of different origin

Year of migration	Length, cm			Mass, g			Numbers		
	Z	P	D	Z	P	D	Z	P	D
1979	12.9	12.8	13.6	20.8	20.5	24.3	8062	521	8649
1980	15.2	13.2	13.5	30.8	20.7	23.6	3055	1925	5458
1981	13.8	15.0	12.9	23.5	30.4	20.3	3614	429	3907
1982	14.0	12.9	13.3	26.4	23.7	23.1	1541	319	6770
1983	14.1	13.2	14.3	25.1	21.3	26.5	5399	1624	4151
1984	13.6	13.1	13.3	21.4	23.3	22.6	1924	422	2626
1985	15.1	13.2	12.8	30.5	20.8	18.6	4169	947	4472
1986	15.9	13.8	12.7	36.6	23.7	19.6	1789	1220	15649
1987	14.0	13.2	13.5	23.5	20.9	23.2	10637	1419	7353

NOTE. Z-Z - hatchery-reared, P-P - overwintered, D-D - wild. The values of the deviation of the mean in all cases were not greater than 0.1. 1986 data - without Batch 29.

Effect of sex. In order to evaluate the sex differences in the size, the mass of the wild smolts was analyzed. The ratio of the mass of the males and females of fish of different age, caught in different years, is shown in Table 27. In 15 cases out of 27 the males were found to be larger than the females, while in 10 cases they were smaller. For the group as a whole, however, these differences were not significant. The average ratio of the mass of the males and females is equal to 1.04 ± 0.05, i. e. it is not significantly different from 1. The same picture is found in the hatchery-reared and overwintered fish.

Effect of age. The average size of smolts of different age is shown in Table 28, from which it follows that the older the smolts the larger they are. An analysis of the literature data shows that in almost all of the populations, about which we have been able to find information, there exists this same tendency (Table 29). The salmon of the Codroy river comprise an exception to this.

Table 27

Ratio of the mass of males and females of wild smolt

Year	Age		
	2+	3+	4+
1979	1.12	1.28	1.16
1980	1.64	0.76	1.21
1981	0.98	1.21	0.95
1982	1.04	1.00	1.09
1983	0.86	0.86	1.14
1984	0.75	1.00	1.14
1985	1.31	1.04	1.26
1986	0.56	0.98	1.11
1987	0.61	0.98	1.06

Table 28

Dimensions of wild and overwintered smolts

Age, years	Length, cm	Mass, g	Numbers, fish
	Wild		
2+	12.4	18.8	2540
3+	13.2	21.9	38402
4+	13.4	22.9	17702
5+	14.0	26.9	392
	Overwintered		
3+	13.2	21.4	7294
4+	13.8	24.4	1532

A paired comparison of the length of smolts of different age, which was carried out in two variants, produced contradictory results. In a comparison of fish that were migrating in the same year, but at different ages, it was evident that the older fish were significantly larger ($p > 0.95$) (Table 30). This was indicated both by the sign test as well as by Student's test: the average difference in length was significantly different from 0. In comparing the length of the smolts from the same year of birth but migrating in different years, both of these tests indicate no significant differences in the body length of the fish of different age (Table 31). In any case the difference in length of smolts of different ages does not exceed 1 - 2 cm, which is apparently less than the annual increment.

Table 29

Length of salmon smolts

River	Average length, mm	Measured length of smolts, mm						
		1+	2+	3+	4+	5+	6+	7+
1	2	3	4	5	6	7	8	9
Luven'ga (White Sea) [1]	132	-	124	132	134	140	-	-
Umba (White Sea) [2]	129	-	116	131	-	-	-	-
Pyalitsa (White Sea) [3]	124	-	118	124	147	-	-	-
Rynda (Barents Sea) [1]	147	-	91	140	147	156	-	-
Sidorovka (Barents Sea) [4]	152 - 157	-	140	147	154	-	-	-
Salatsa (Baltic Sea) [5]	127	107	132	146	180	-	-	-
Codroy (Canada) [6]	150	-	145	153	156	128	-	-
Big Salmon (Canada) [7]	-	-	140	146	157	-	-	-
Western Arm Brook (Canada) [8]	184	-	-	165	183	213	-	-
Berimul (Ireland) [9]	140	131	140	149	-	-	-	-
Kvajeimsana (Norway)	152	119	147	155	-	-	-	-
Orkla (Norway)	132	-	114	129	137	142	-	-
Beiarel'va	136	-	-	-	125	134	141	140

NOTE. 1 - our data; 2 - Kazakov and Semenova, 1986; 3 - Kazakov, 1987; 4 - Kuz'min, 1985; 5 - Mitans, 1968; 6 - Murray, 1968; 7 - Jessop, 1975; 8 - Chadwic et al., 1978; 9 - Piggins and Mills, 1985; 10 - Hesthagen et al., 1986; 11 - Hesthagen and Garnas, 1984; 12 - Jensen and Johnsen, 1986.

For comparing the differences in the measured length of the smolts of different age with the annual growth increments we carried out the back calculation of the length of the salmon of different age. The analysis was carried out in two variants: for the fish of different generations migrating in one and the same year (1983) and for the fish of the same generation (hatching in 1978, migrating in 1980 - 1983). On the basis of Table 28 it may be calculated that the differences in the length of the smolts of neighbouring age groups comprise 2 - 8 mm, while between the 2+ and 5+ fish the difference comprises 16 mm. Meanwhile, the growth increment in the year preceding the transition into the sea is much greater - 34 - 58 mm (Table 32), i. e. the difference in length of of the smolts of different age should be

Table 30

Differences in the average measured length of smolts, cm, caught in the same year

Year of migration	Wild		Overwintered
	3+ – 2+	4+ – 3+	4+ – 3+
1979	+1.33	+0.16	+1.04
1980	-0.32	+0.04	+1.20
1981	+0.28	-0.18	+0.79
1982	+1.54	+0.25	+0.95
1983	+2.59	+0.90	+1.15
1984	+0.32	+0.60	+1.05
1985	+1.07	+0.15	+0.98
1986	+0.42	+0.06	+0.90
1987	+2.43	+0.27	+0.08
Average	1.07 ± 0.33	0.25 ± 0.11	0.90 ± 0.11

Table 31

Differences in the average measured length of smolts, cm, of the same generation migrating in different years

Generation	Wild		Overwintered
	3+ – 2+	4+ – 3+	4+ – 3+
1976	+1.09	-0.75	+2.61
1977	-0.89	+0.63	-1.14
1978	+0.66	+2.16	+1.17
1979	+2.80	-0.68	+0.43
1980	+1.31	-0.16	+0.97
1981	+0.83	-0.18	+1.80
1982	+0.83	+0.88	-0.49
Average	0.83 ± 0.43	0.27 ± 0.33	0.76± 0.49

Table 32

Absolute growth increment of calculated body length, mm, of juvenile salmon in the year preceding the migration

Group	2+	3+	4+	5+
Juvenile fish of same year of birth	58	58	36	34
Juvenile fish of same year of migratic .	49	48	45	34

Table 33

Relative growth increment of calculated body length (percentage of measured length) in wild smolts of different age

Year of life	2+	3+	4+	5+	x	V
1st	38.0 / 29.5	29.5 / 29.5	26.0 / 27.5	24.0	29.1	15
2nd	38.5 / 41.5	27.5 / 28.0	18.5 / 20.0	16.5	27.2	36

NOTE. Across the diagonal - data for fish of the same year of migration and for fish of the same year of birth.

determined by a different rate of growth. In Figure 10 are shown the results of calculations expressed as percentages of the body length. In all four age groups one may compare the growth increments in the first and second years of life. For both indices there exists a similar tendency: a decrease in the yearly increment in several of the 2+ - 5+ age groups. This, is expressed much more strongly, however, in the second year (Table 33). If one compares the dimensions attained, rather than the rates of growth, then these dimensions appear most similar in the fish of the same age in the year of migration (V = 7%). The dimensions of the fish in the year preceding the migration are more variable (V = 16%), while the maximal differences are noted 2 years following the migration (V = 32%). These results corroborate the opinion that smoltification is determined by the rate of growth and by the size attained, rather than by the age of the salmon. Thus, differences in age do not exert a significant effect on the dimensions of the migrating fish. The smolts that are migrating at different ages are differentiated not so much by their dimensions as by their rate of growth.

Effect of the release conditions. The average (over many years) mass of the released downstream migrants is 21 g, which is 1 g less than the many-year mass of the smolts. The mass of the salmon which are migrating in the year of their release is already higher than the mass of the wild smolts (Table 34). On the basis of the many-year data one may trace the following pattern of change of the average mass of the hatchery-reared

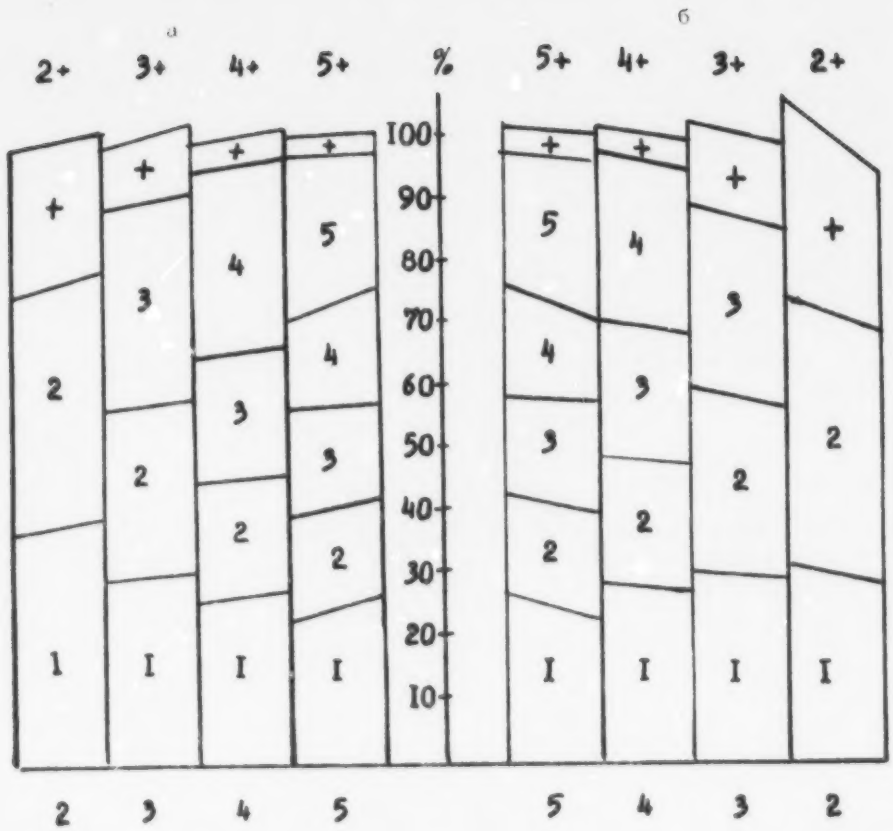

Рис.10. Расчисленная длина смолтов разного возраста $x \pm m$. По вертикали – длина (процент от измеренной длины), по горизонтали – возраст смолтов; а – рыбы одного года миграции, б – одной генерации.

Figure 10. Calculated length of smolts of different age $x \pm m$. Along the vertical - length (percentage of measured length), along the horizontal - age of smolt; a (а) - fish of the same year of migration, b (б) - of the same generation.

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juvenile fish that were released into the river (Figure 11). The mass of the juvenile fish which are migrating in the year of their release is 25% greater than the mass of the released downstream migrants ($p > 0.95$), while the mass of the fish that remain in the river is 30% smaller ($p > 0.95$). The mass of the overwintered smolts migrating at an age of 3+ is 6% greater than the mass of the released fish and 9% greater than the mass of the parr remaining in the river. This tendency, however, is not significant. In the generations released in 1985 and 1986 the smolts at an age of 3+ were found to be smaller than not only the released fish but also the salmon remaining in the river (Table 34). In those that overwintered at 4+ the average

Table 34

Mass of juvenile fish of hatchery origin

Year of	Released downstream migrants	Juvenile fish remaining to overwinter	Migrating juvenile fish		
			2+	3+	4+
1978	18.9	18.1	21.2	20.4	35.3
1979	17.9	17.6	20.8	20.1	30.8
1980	29.8	28.9	30.8	30.4	29.6
1981	19.5	19.1	23.5	23.3	26.6
1982	18.3	17.9	26.4	19.5	23.9
1983	21.7	20.6	25.1	23.4	22.9
1984	17.8	17.4	21.4	19.8	27.2
1985	24.2	23.2	30.5	23.1	21.6
1986	22.2	21.3	36.6	20.6	21.8
Many-year average	21.1 ± 0.1	20.7 ± 0.1	26.3 ± 0.2	22.5 ± 0.1	25.6 ± 0.1

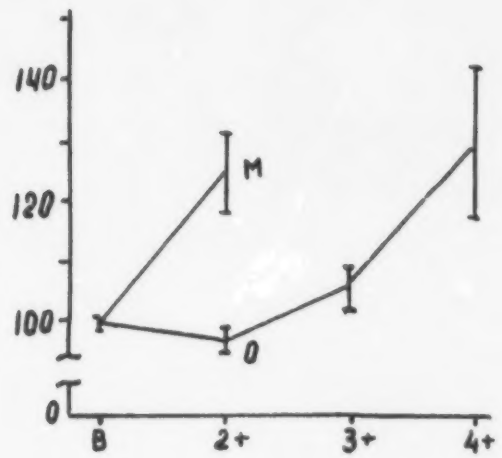


Рис.11. Масса молоди семги заводского происхождения при выпуске и после него.

По вертикали: масса рыб ($x \pm m$), процент от массы выпускаемых покатников; по горизонтали: возраст, м – мигрирующие, о – оставшиеся, в – выпуск.

Figure 11. Mass of juvenile salmon of hatchery origin at and after release. Along the vertical: mass of fish ($X \pm m$), percentage of mass of released downstream migrants; along the horizontal: age, м - migrating, о - remaining, в - release.

mass was 30% greater than the mass of the released downstream migrants and 33% greater than the mass of the juvenile fish remaining in the river (Figure 11), although, as is evident from Table 34, on three occasions the mass of such fish was lower than that of the released downstream migrants, and on two occasions it was lower than that of the juvenile fish remaining to overwinter. A correlational analysis was carried out in order to evaluate the effect of the release conditions on the mass of the juvenile fish of hatchery origin. The characteristics of the release conditions were presented in Table 9.

The following relationships were found to be significant.

The greater the average mass of the released juvenile fish (+0.67) and the more juvenile fish were released by way of the holding net (+0.68), the greater was the mass of the salmon which migrated in the year of the release.

The mass of the fish remaining to overwinter was positively correlated with the average mass of the released downstream migrants (+0.99) and with the proportion of the juvenile fish migrating in the year of the release (+0.79). The mass of those remaining is not correlated with the mass of the salmon migrating at an age of 2+. This index is decreased with an increase in the number of fish remaining to overwinter, in both absolute (-0.73) as well as relative (-0.79) terms. The mass of the overwintered smolts, migrating at an age of 3+ is positively correlated with the mass of the released juvenile fish (+0.91) and with the mass of the fish remaining in the river to overwinter (+0.92), and is negatively correlated with the number of fish released (-0.69).

4. 4. Morphological characteristics

The difference in the appearance of the hatchery-reared and wild juvenile fish induced us to carry out an analysis of the morphological indices of the juvenile salmon of different origin. 100 specimens of juvenile salmon were examined by us according to the scheme accepted in the PINRO (The N. M. Knipovich Polar Scientific Research Institute of

Marine Fisheries and Oceanography) (Table 35). Approximately the same number of skulls of the hatchery-reared and wild juvenile salmon were sent to the Zoological Institute of the Academy of Sciences of the USSR, where this material was studied by A. V. Salmanov, a post-graduate student in the Laboratory of Ichthyology (Salmanov, 1986, 1989). Significant differences between the hatchery-reared and the wild juvenile fish were found in 13 of the 20 indices studied (Table 35).

A similar analysis was carried out on the hatchery-reared and wild juvenile salmon in the Umba river (Kazakov and Semenova, 1986). Of the 13 indices that were compared, the ratios of the measurements of the features of the hatchery-reared and wild juvenile fish coincided for the Luven'ga and the Umba in six: the preventral distance, the pectoventral distance, the length of the caudal peduncle, the maximal depth of the body, the length of the upper jaw and the length of the postorbital section.

The predorsal distance in the hatchery-reared and wild fish studied by us did not differ, while according to the data of Kazakov and Semenova it was significantly greater in the hatchery-reared fish.

The postdorsal distance in our material was greater in the wild juvenile fish, but in the data for the Umba river it was greater in the hatchery-reared fish. The minimal depth of the body of the hatchery-reared fish, according to our data, is significantly greater than in the wild fish, while Kazakov and Semenova reported that the wild juvenile fish exceed the hatchery-reared fish in the size of this feature. On the basis of the length of the head we found no difference between the groups being compared, while the wild juvenile fish of the Umba salmon have a comparatively larger head length than the hatchery-reared fish.

In the Luven'ga river a longer snout and lower jaw were found in the hatchery-reared fish, while in the Umba these features are longer in the wild fish. According to the data of Kazakov and Semenova, the eye diameter of the wild and the hatchery-reared juvenile fish was similar, while both measurements of the eye diameter, vertical and horizontal, made by us, indicated that the eye of the hatchery-reared juveniles was comparatively wider than in the wild fish (Kazakov and Semenova, 1986).

Table 35

Morphometric indices of the juvenile fish

Index	Size of index (percentage of body length according to Smith[14])	
	hatchery-reared (54)	wild (46)
Predorsal distance	42.10 ± 0.13	41.67 ± 0.15
Postdorsal distance	41.84 ± 0.23	43.88 ± 0.24 **
Preventral distance	50.24 ± 0.19	49.13 ± 0.37 **
Pectoventral distance	29.42 ± 0.22	28.73 ± 0.23 *
Length of caudal peduncle	19.92 ± 0.16	20.23 ± 0.42
Length of dorsal margin of caudal peduncle	14.83 ± 0.13	13.91 ± 0.18 **
Length of ventral margin of caudal peduncle	15.72 ± 0.14	16.22 ± 0.20 *
Maximal depth of body	17.97 ± 0.15	17.45 ± 0.15 *
Minimal depth of body	7.39 ± 0.05	6.98 ± 0.06 **
Length of head	22.90 ± 0.10	22.73 ± 0.12
Length of snout	5.23 ± 0.05	4.96 ± 0.10 *
Length of middle part of head	13.87 ± 0.11	13.84 ± 0.14
Length of lower jaw	8.68 ± 0.11	7.99 ± 0.14 **
Length of upper jaw	6.77 ± 0.07	6.91 ± 0.11
Width of upper jaw	2.40 ± 0.03	2.05 ± 0.04 **
Horizontal diameter of eye	5.70 ± 0.07	4.98 ± 0.10 **
Vertical diameter of eye	5.33 ± 0.06	4.87 ± 0.10 **
Length of postorbital section	12.10 ± 0.08	12.37 ± 0.01 **
Length of subopercular bone	6.33 ± 0.05	6.26 ± 0.07 *
Distance from end of upper jaw to posterior margin of preopercle	7.96 ± 0.07	7.85 ± 0.08

* $p > 0.95$
** $p > 0.99$

[14] The Russian version "Смит" (Smit) could be a transliteration of Smith or Smitt. [Tr.]

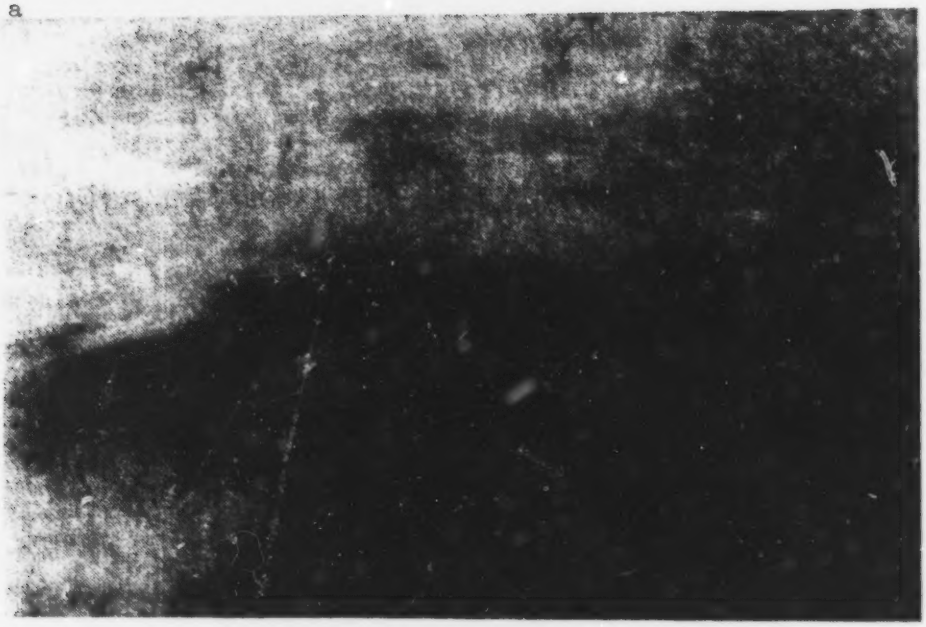
A. V. Salmanov (1986, 1989), having compared the hatchery-reared and the wild fish on the basis of 41 morphological characters of the skull and on the basis of 10 indices pertaining to the head, revealed a whole series of differences both in the proportions of the skull of the juvenile fish of different origin, as well as in the form of the individual bones of the visceral skeleton of the head. The level of these differences exceeds the level of the differences of similar indices between wild salmon living in rivers in the basin of different seas (Salmanov, 1989). The most pronounced differences between the hatchery-reared and the wild juvenile salmon of the Luven'ga river were noted by him in the bones associated with the jaw apparatus. These differences may in some measure determine the deviations in the food behaviour that were noted in the hatchery-reared salmon that got into the river (Chebanova et al., 1988).

It is much more complicated to interpret the possible meaning of the differences in the postdorsal or preventral distances, and the dimensions of the jaws or of the eye, all the more so since for the salmon of the neighbouring Umba river the differences of some of the morphometric indices have a different character.

However, differences in the dimensions of the fins have been found by all investigators not only in the salmon (see Kazakov and Semenova, 1986) but also in the sea trout (Tamarin and Chernitskii, 1986). Necrosis is found to manifest a considerable effect on the dimensions of the fins. Necrosis of the fins has been found in a considerable portion of the fish that were reared in the Kandalaksha fish hatchery. Most frequently the dorsal fin is affected, more rarely - the ventral and caudal fins, The frequency of the affliction may vary considerably in different batches released in the same year (Table 36). Among the wild smolts not a single fish has been found with necrosis, while among the overwintered fish about half comprised individuals in which the dorsal fin had regenerated following necrosis (Figure 12). The paired and caudal fins were entire in all of the overwintered fish.

The causes of the necrosis are unknown up to the present time. Some authors assign the main role in the infirmity of the fins to bacteria (Schneider and Nicholson, 1980), while others put the blame on disturbances in the metabolism as a consequence of some

a



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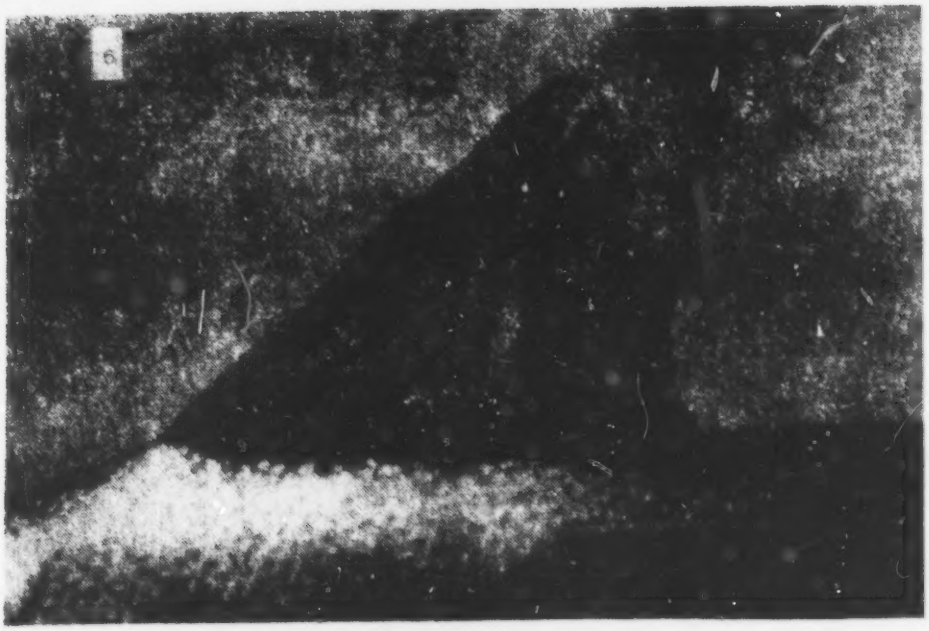

Figure 12. Dorsal fin.
a (а) - hatchery-reared salmon, b (б) - overwintered salmon,
v (в) - wild salmon [on following page].

Рис.12. Спинной плавник.
а – заводской сеголеток, б – перезимовавший, в – дикий.

Figure 12, v

deficiencies in the feeding and improper maintenance (Chechenkov et al., 1979). Injury to the fins, especially to the dorsal fin, is associated with aggressive behaviour of the juvenile salmon, attacks and bites (Abbott and Dill, 1985). Studies in recent years provide evidence that the necrosis of the fins is a generalized affliction, in which there occurs a profound reorganization of vitally important biochemical systems and, above all, those associated with membranes (Gruzdev et al., 1983).

In the fish-hatchery conditions those fish that have lost their fins may grow and develop just like the healthy fish, since food is present in excess, predators are absent and there

Table 36

Frequency of fin necrosis disease in juvenile fish released from the Kandalaksha fish hatchery

Fin	Batch	
	26 (46 fish)	28 (52 fish)
Dorsal	99* / 96 - 100	50 / 36 - 64
Pectoral	44 / 34 - 54	4 / 0 - 11
Pelvic	13 / 1 - 19	0 / 0 - 2
Caudal	14 / 0 - 22	0 / 0 - 2

* Average value / 95% confidence interval

is no need to oppose the current, since the velocity of the movement of the water in the breeding tanks is much lower than in the natural habitats of the juvenile Atlantic salmon. A completely different situation arises after the release of the fish into the river. Here it is more difficult for the fish with defective fins to occupy the optimal position in the current, which is necessary for its feeding and for protection against predators, which may determine the high mortality of the fish with necroses. Apparently, during the first period following the release the mortality of the hatchery-reared juvenile fish is indeed determined by the predation.

In the Luven'ga river fish with necrosis of the paired fins are encountered among the migrating hatchery-reared juvenile fish, both immediately after the release and also after the passage of considerable time, which indicates that in the absence of predatory fishes such juvenile salmon may survive during the summer months, which are favourable from the aspect of the food conditions. Apparently, the mortality of such fish occurs during the autumn and winter periods, when the food supply in the river is depressed and it is more difficult for the salmon to procure food; one may reach a conclusion concerning this on the basis of the fact that we did not encounter even a single individual with necrosis of the fins among the overwintered fish in the Luven'ga river. The paired and caudal fins of the overwintered fish are completely whole, while the dorsal fin has traces of regeneration in approximately half of the the individuals examined.

As was shown in Chapter 3, the proportion of fish that survive through the winter comprises 1 - 3% of the total numbers remaining in the river to overwinter. From Table 36, where the confidence interval is shown for the frequency of necrosis for each fin, it can be seen that with such a low survival rate there may be present among the dead fish those with necrosis of the paired fins, while among the survivors are found only fish without necrosis of the fins and some fish with necrosis of the dorsal fin. At the same time some observations provide grounds for supposing that in the fish that get into the river from the hatchery and change over to feeding on natural food there occurs a regeneration of the fins. Thus, the fish in batches 14 and 15 were tagged by amputation of the ventral and anal fins. From the time of the amputation up until the release from the hatchery, i.e. from the middle of March up to the end of June, no regeneration of the fins occurred. After the release, however, during July and August, the fins in the fish remaining in the river regenerated to such a degree that the tagged fish could be distinguished only by the thickening of the fin rays at the site of amputation.

In 1986 a batch of hatchery-reared silvery smolts (No. 29) were placed into the holding net that had been set up in the lower reaches of the Luven'ga. The dorsal fin was necrotized in all of the fish. The fish fed mainly on drifting material that passed through the netting of the holding net and only occasionally fed on granules. In these fish regeneration of the dorsal fin commenced as early as two weeks later. Thus, the absence of necrosis in the overwintered fish may be explained both by an elimination of the diseased fish when they get into natural conditions and also by the regeneration of the affected fins as a result of the metabolism returning to normal.

In a comparison of the length of the fins of juvenile fish of different origin it was established that in the wild, the overwintered and the hatchery-reared migrating juvenile salmon it is the pectoral fins that are the longest, while the shortest are the pelvic fins. (Table 37). In all three groups that were studied in the river the right paired fins were longer than the left, and moreover for the pectoral fins these differences were significant. From this table it is evident that the overwintered fish are significantly different from the hatchery-reared and

Table 37

Relative length (percentage of body length according to Smith [15]) of the fins of juvenile salmon

Index	Group of juvenile fish		
	wild (50 fish)	overwintered (33 fish)	hatchery-reared * (33 fish)
Body length, cm	13.6 ± 0.1	12.9 ± 0.3	13.9 ± 0.2
Dorsal	12.6 ± 0.2	11.6 ± 0.2	2.9 ± 0.3
Left pectoral	15.0 ± 0.1	14.3 ± 0.2	13.7 ± 0.2
Right pectoral	15.6 ± 0.1	14.7 ± 0.2	14.7 ± 0.2
Left pelvic	10.3 ± 0.1	9.7 ± 0.2	9.7 ± 0.2
Right pelvic	10.7 ± 0.1	10.3 ± 0.1	9.9 ± 0.3
Upper caudal	14.3 ± 0.1	14.0 ± 0.2	13.5 ± 0.2
Lower caudal	14.8 ± 0.1	14.4 ± 0.2	14.3 ± 0.2

* Data for fins not affected by necrosis, with the exception of the dorsal fin.

Table 38

Coefficients of linear correlation of the length of the body and of the fins of the juvenile salmon ($p > 0.95$)

Fin	Wild	Overwintered
Dorsal	0	0
Left pectoral	-0.50	-0.37
Right pectoral	-0.50	-0.49
Left pelvic	-0.54	-0.42
Right pelvic	-0.50	-0.51
Caudal, upper lobe	-0.35	0
Caudal, lower lobe	-0.57	-0.50

the wild fish on the basis of the length of the fins. For this reason, for evaluating the possibility of making a correct comparison of the fins of the juvenile fish of the different groups, it is necessary to establish how the body length is related to the length of the fins. For this purpose a correlation analysis was carried out. The results of the latter, presented in Table 38, show that in those cases when there is a dependency it is negative, i.e. in the longer fish the fins are comparatively shorter. Consequently, in the overwintered fish the fins should be

[15] See Footnote 14 to Table 35 on Page 74. [Tr.]

Table 39

Coefficient of variation of the fin length of juvenile salmon, %

Fin	Wild	Overwintered	Hatchery-reared
Dorsal	9.6	10.0	46.0
Left pectoral	5.1	10.0	10.0
Right pectoral	6.0	8.8	7.0
Left pelvic	6.4	9.0	11.0
Right pelvic	6.6	6.2	14.0
Caudal, upper lobe	4.7	9.6	9.0
Caudal, lower lobe	6.9	6.3	10.0

comparatively longer than in the wild fish. However, in the overwintered fish the fins are shorter, by 2 - 8%, than than in the wild fish (Table 37). These differences are significant for all the fins except the caudal fin. Taking into account the existing correlation between the body length and the relative length of the fin, the difference should be even more significant. The fins of the hatchery-reared juvenile fish were found to be the shortest, even in those cases when fins without any symptoms of necrosis were taken into consideration (Table 37). Significant differences in the fin length of different groups of fish were found not only in the analysis of the average values but also in the analysis of the variation (Table 39). In the wild fish the length of the dorsal fin was the most variable (coefficient of variation - 9.6%), while the length of the upper lobe of the caudal fin was the least variable (4.7%). In the overwintered fish the most variable was the length of the left pectoral and of the dorsal fins (10%) and the least variable was the length of the right pelvic fin (6.2%). In the hatchery-reared juvenile fish the coefficient of variation of the length of the dorsal fin was 46%, which is explained by the necrosis that was noted in all of the studied fish. Among the fins that were not affected by the necrosis, the most variable was the pelvic fin[16] (14%) while the least variable was the right pectoral fin (7%). With the comparison of the coefficient of variation of the fin length of the wild and overwintered fish it may be noted that in 5 cases out of 7 this index was lower in the overwintered fish as compared with the wild fish. Significant differences in

[16] Sic. Not indicated here whether left or right in the Russian text. [Tr.]

the variability (according to Fisher's criterion) were noted for the pectoral fins and the upper lobe of the caudal fin. In the hatchery-reared fish the variability is significantly higher than in the wild fish for all of the fins, except the right pectoral fin. In the comparison of the overwintered and the hatchery-reared fish a significantly greater variability in the latter was noted for the left pectoral, dorsal and pelvic fins and for the lower lobe of the caudal fin.

The differences in the comparative length of the fins in the hatchery-reared and the overwintered juvenile fish were apparently conditioned by the elimination, after the release, of the fish with less strongly developed fins. M. F. Vernidub (1977) proposed that the cause of the lesser length of the lobes of the caudal, pelvic and pectoral fins, found by him in the hatchery-reared fish, as compared with wild fish, is their abrasion on the concrete bottom of the breeding tanks and their destruction by *Saprolegnia* . Yu. A. Shustov (1983) proposed another explanation for these facts; he assumed that in nature there occurs a selection of those juvenile fish in which well developed fins are present, as a result of a hereditary factor. Fish with underdeveloped fins die. In the fish hatchery all of the juvenile fish survive, and in the end the average index of the fin development of the fish is lowered (Shustov, 1983, p. 121). As the author himself points out, this point of view should be confirmed by experimental data. The data that we have allow us to do this. As is evident from Table 37, the length of the fins of the hatchery-reared fish is significantly lower, by 5 - 10%, than that of the wild fish. If this were determined only by an abrasion of the fins, then, in the first instance, the variability in the fin lengths of the hatchery-reared and of the wild fish would be similar. As a matter of fact the variability in the length of the fins of the hatchery-reared juvenile fish is significantly greater, by 1.5 - 2 times, than in the wild fish. Such a high variability may be explained by the absence of a selection of the hatchery-reared juvenile fish on the basis of such a feature, as the development of the fins. And, secondly, if the difference in the length of the fins in the natural and the hatchery-reared fish was determined by abrasion, then the abrasion effect would be more noticeable for the lower lobe of the caudal fin than for the upper lobe, which does not come into contact with the bottom of the tank. However, from the data in Table 37, it can be seen that the difference is smaller for the lower lobe than for the upper lobe (6 and

3%, respectively). The results of an experiment on the rearing of juvenile salmon under different conditions also did not corroborate the hypothesis concerning the mechanical abrasion of the fins of the hatchery-reared fish. In fish that grew in a smooth-walled plastic tank the pectoral fins were found to be 7% shorter than in fish that grew in a concrete tank (Safonov et al., 1990). In the case of an abrasion of the fins this pattern would be reversed. It is evident that the different requirements presented to the locomotory system of the juvenile salmon in the two experimental variants comprised the cause of the differences in this case. This is also corroborated by the smaller variability in the length of the fins and the greater manœuvrability of the fish from which a greater locomotory activity was required in the developmental process (Safonov et al., 1990).

The growth of the fins in the ontogeny of the juvenile salmon is probably determined by the locomotory activity of the fish, which is dependent on the mobility of the food objects and the velocity of the water current. Thus, in a comparison of juvenile Atlantic salmon that grew in two tributaries of the Miramichi river, it was found that the fish living in the tributary with a strong current were characterized by longer paired fins and a more elongate body, as compared to the fish living in the tributary with a weak current (Riddell and Leggett, 1981). The comparatively greater development of the pectoral fins of the Atlantic salmon, in comparison with the juvenile sea trout is also explained by the preference of the former for habitats with a higher current velocity (Jones, 1975).

All of this indicates the important role of the external conditions for the growth of the fins of the juvenile salmon. It is known that the living conditions for the fish differ considerably in nature and in fish hatcheries. The territory occupied in the river by an individual large parr may be as much as several square meters. The size of the area per one individual may be divided by some tens or even hundreds in fish hatcheries, which increases the probability of injury to the fins as a result of an activization of the aggressive behaviour of the juvenile fish. The mobility of the fish in the breeding structures is also considerably lower than in the natural habitats of the juvenile salmon (Safonov, 1987).

Thus, the state of the fins of the hatchery-reared juvenile salmon may be an indicator of their quality and should be controlled during the rearing and especially prior to their release into the natural conditions.

4. 5. Migration

The migration of juvenile salmonid fishes downstream along a river for the transition into the sea is a complex behavioural act. The migration may be characterized by various parameters, each of which reflects some one feature of the migration. For this reason it is a fairly complex matter to compare the migration of the juvenile fish of different groups.

Calendar characteristics. The calendar characteristics of the migration are the dates of registration of the first and last fish of a given group (beginning, end), as well as the date on which occurred the maximum (peak) of the migrating fish. These characteristics of the migration of the wild, overwintered and hatchery fish are illustrated in Figure 13. As can be seen from the figure, over the course of 10 years the overwintered fish began to migrate at the same time as the wild fish on 4 occasions, while 3 times they started earlier and 3 times - later than the wild fish. The peak of migration of the overwintered and the wild fish coincided in three cases, in 5 years the peak of migration of the overwintered fish was noted earlier than in the wild fish, while in two cases it was noted later. The overwintered fish completed their migration earlier than the wild fish in six cases, later - in one case, and simultaneously - three times. In Table 40 are presented the average many-year calendar characteristics of the migration of the different groups of juvenile fish.

The calendar characteristics of the migration of the hatchery-reared juvenile fish are determined in large part by the characteristics of the release of the fish from the hatchery. In 1978 and 1979 the first hatchery fish appeared in the fish counting weir on the day of the release of the first batch in the given year. In 1980-87 some time passed between the release of the first batch and the appearance of the first fish in the FCW (Figure 13). This is apparently connected with the fact that in 1978 and 1979 the first batches were released 1.3 km

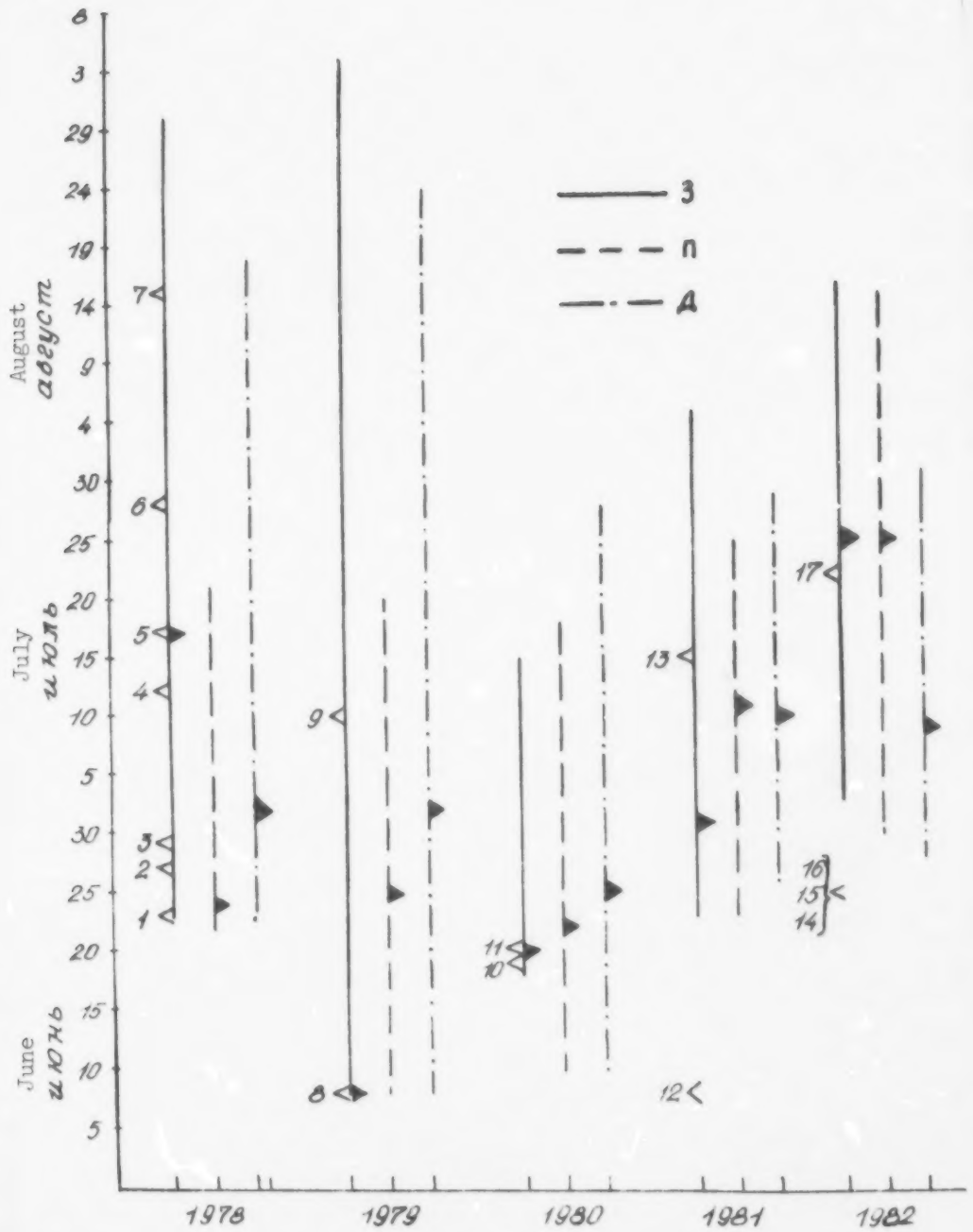

Figure 13. Calendar dates of migration of salmon

——— z (з - заводские - zavodskie) hatchery-reared

– – – – p (п - перезимовавшие - perezimovavshie) overwintered

—·— d (д - дикие - dikie) wild

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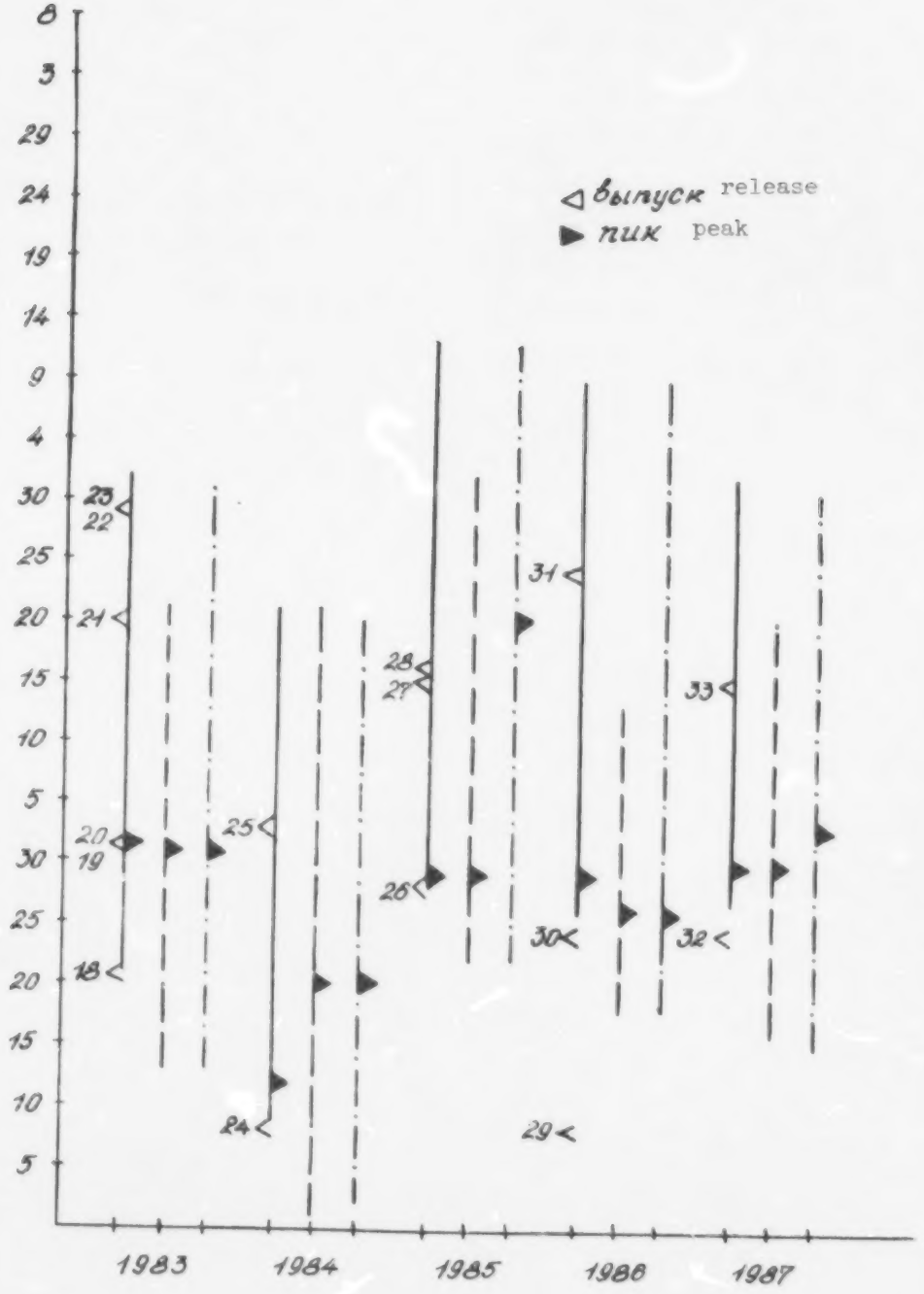


Рис.13. Календарные сроки миграции семужат.

△ - выпуск (vypusk) - release

▲- пик (pik) - peak

Table 40

Calendar characteristics of the migration of juvenile salmon

Group	Beginning	Peak	End
Wild	June, 16 ± 3	July, 2 ± 3	August, 1 ± 3
Overwintered	June, 15 ± 3	June, 29 ± 3	July, 23 ± 3
Hatchery-reared	June, 21 ± 3	June, 29 ± 5	August, 9 ± 5

Table 41

Distance of point of release from the mouth of the river for the batches of juvenile fish, the peak of migration of which coincided or did not coincide with the date of release

Year	Batch	Distance, km
	Coincident	
1978	5	1.3
1979	8	1.3
1980	10	3.9
1983	19	3.9
	Not coincident	
1981	12	23.5
1982	17	14.0
1984	24	14.0
1985	26	14.0
1986	30	14.0
1987	32	14.0

from the mouth of the Luven'ga river, while in the following years these releases were at 14 and 23.5 km from the estuary. The peak of the migration of the hatchery-reared juvenile fish occurred on the day of the release of the next batch of fish in 1978, 1979, 1980 and 1983; in the remaining years the peak was noted later than the day of release. The analysis of the conditions of release of the batch, forming the peak, showed that a coincidence of the dates of a release and of a peak are observed with releases 1.3 and 3.9 km from the mouth of the river, while there was no coincidence with releases at 14 and 23.5 km from the mouth (Table 41). No coincidence of the dates of the migration peaks of the hatchery-reared and wild fish were noted over the entire period of these observations. The last hatchery reared fish

departed into the sea after the wild fish in six out of the 10 cases, and earlier in three cases. Coincidence of the dates of termination of migration was noted once.

Duration of the period of migration. We define the number of days passing between the appearance of the first migrating fish and the appearance of the last as the duration of the migration of 100% of the fish, and we call this the total period of migration. However, the migration of the main part of the smolts occupies only a small part of the total period of the migration. For this reason we separate out the duration of the migration of the first 5% and the last 5% of the migrants. The duration of the migration of the first and last 5% of the fish taken together gives the duration of the period of migration of the extreme 10% of the fish (10% period of migration); this period in the wild smolts takes up from 49 to 64% of the total period of migration, comprising 49 days on average (Table 42). In the overwintered fish the total period of migration occupied 39 days on average, while the 10% period occupied 46% of the total period (Table 43).

Table 42

Duration of the migration of wild smolts

Year	Duration of total period	"Central" 90% of fish	"Extreme" 10% of fish
1979	78	24* / 31	54 / 69
1980	49	22 / 45	37 / 55
1981	34	14 / 41	20 / 59
1982	34	12 / 41	20 / 59
1983	49	22 / 45	27 / 55
1984	49	24 / 49	25 / 51
1985	51	26 / 51	25 / 49
1986	53	21 / 40	32 / 60
1987	47	17 / 36	30 / 64
Average value	49 ± 4	20 ± 1 / 42 ± 2	29 ± 1 / 58 ± 2

* Here and in Tables 43 and 44: days / percentages of the duration of the total period of migration.

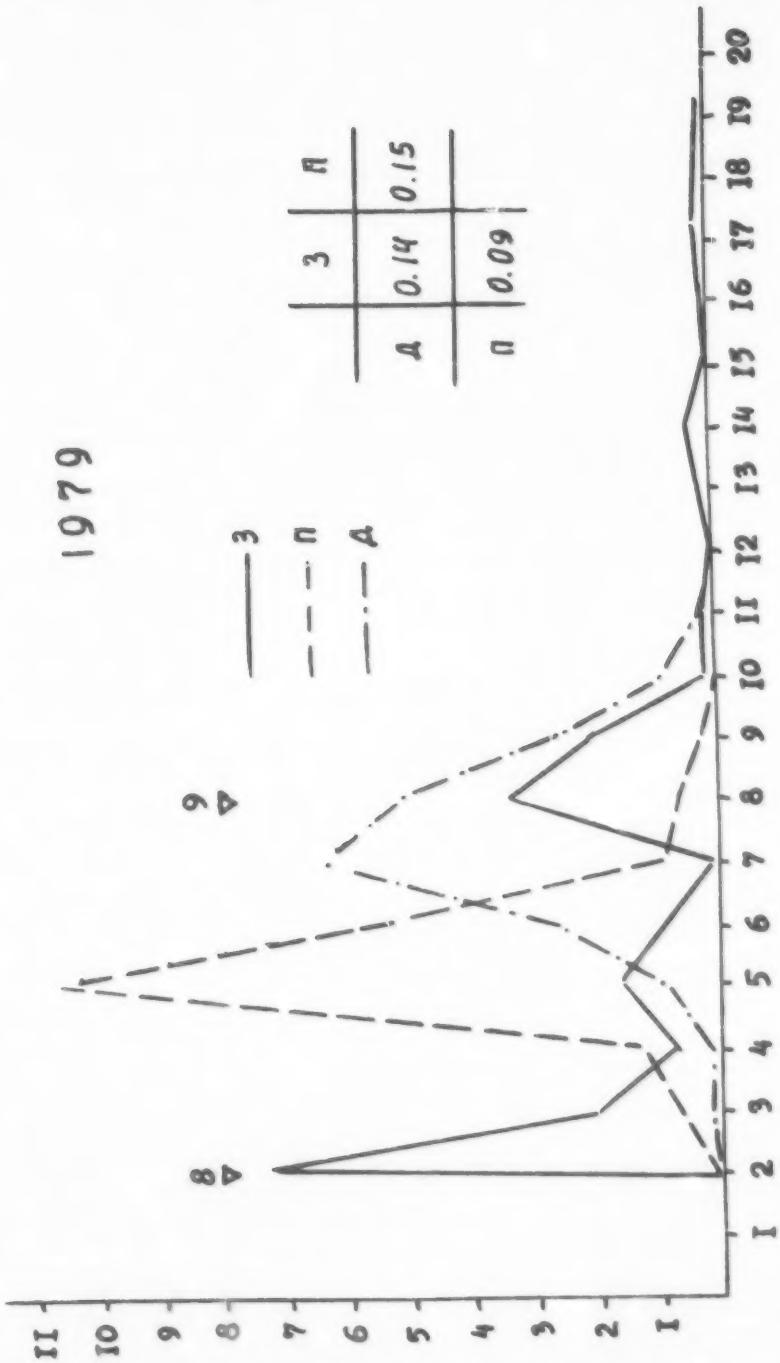


Figure 14. Dynamics of the migration of juvenile fish of different origin.

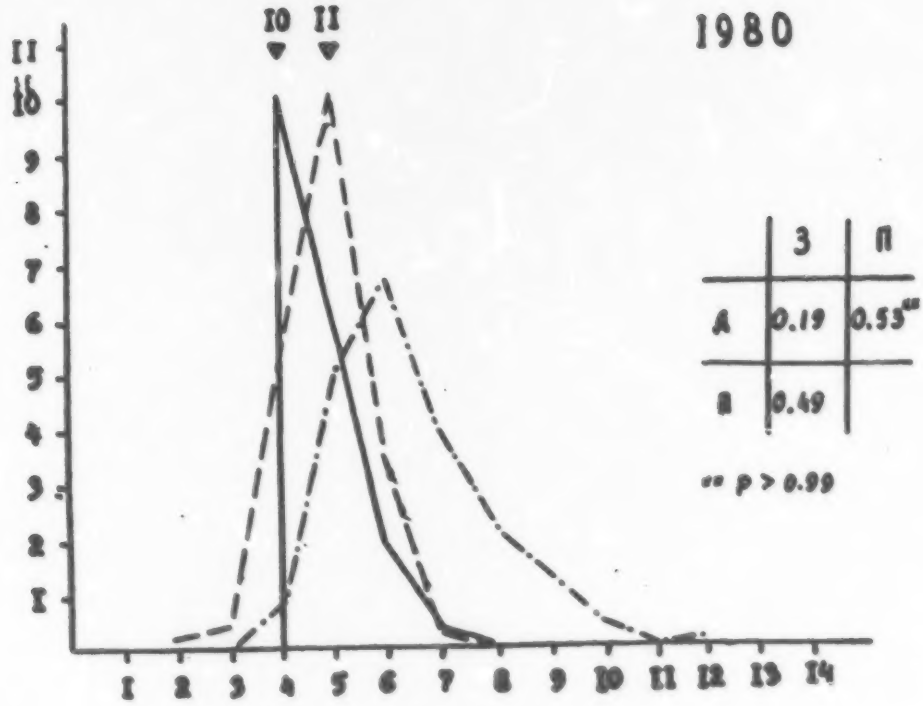
Along the vertical: numbers of juvenile fish migrating per day, percentage of the total number of migrants of a given group; along the horizontal: time, five-day periods. The first five-day period commences on June 1st. The numbers of the batches released are designated by numerals. In the table - matrix of coefficients of the paired correlations of the daily abeolute numbers of migrating juvenile fish of the different groups.

——— z (з - заводские - zavodskie) hatchery-reared

– – – – p (п - перезимовавшие - perezimovavshie) overwintered

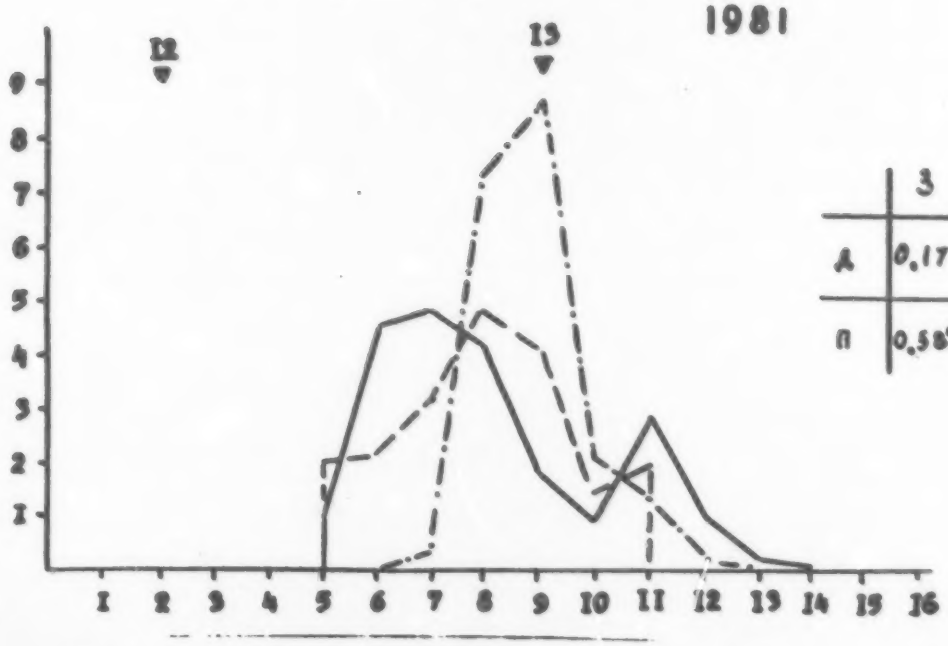
—·—·— d (д - дикие - dikie) wild

[Figure 14 continued over following four pages.]



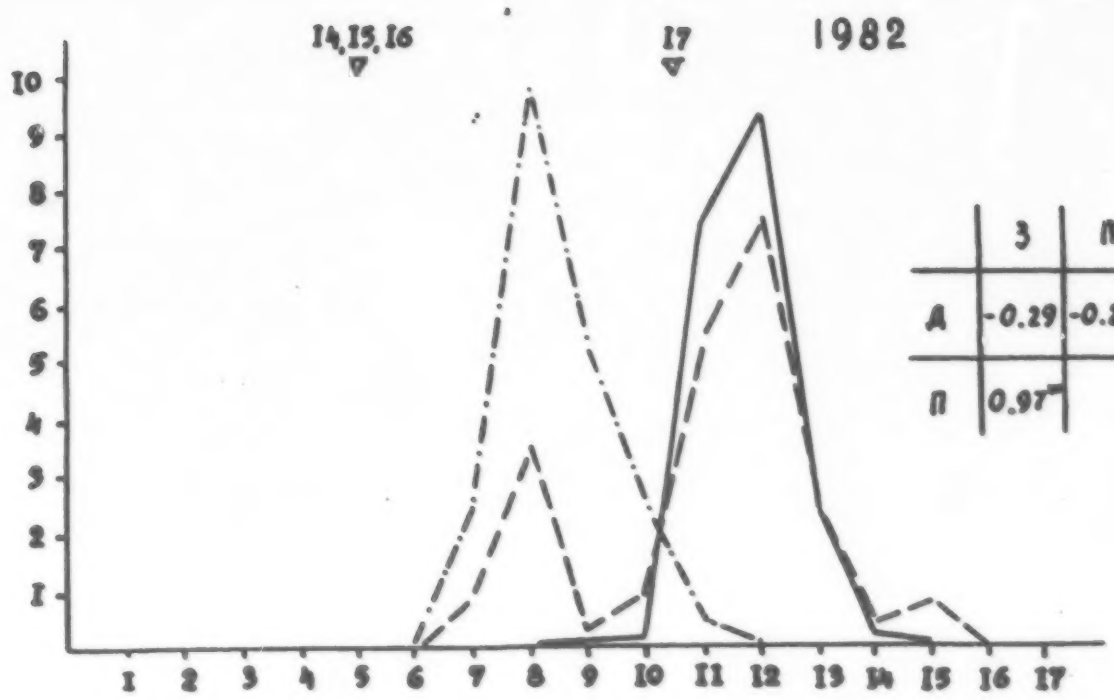
	З	П
А	0.19	0.55**
П	0.49	

** p > 0.99



	З	П
А	0,17	0,53**
П	0,58**	

Figure 14. [continued - 1980, 1981]



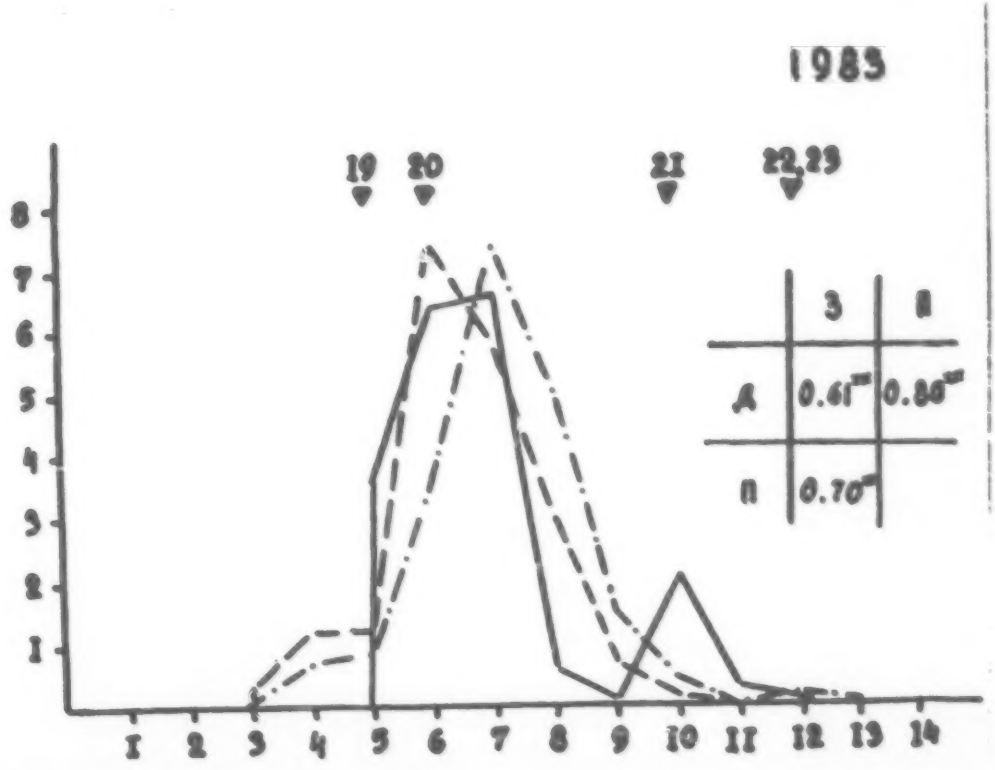
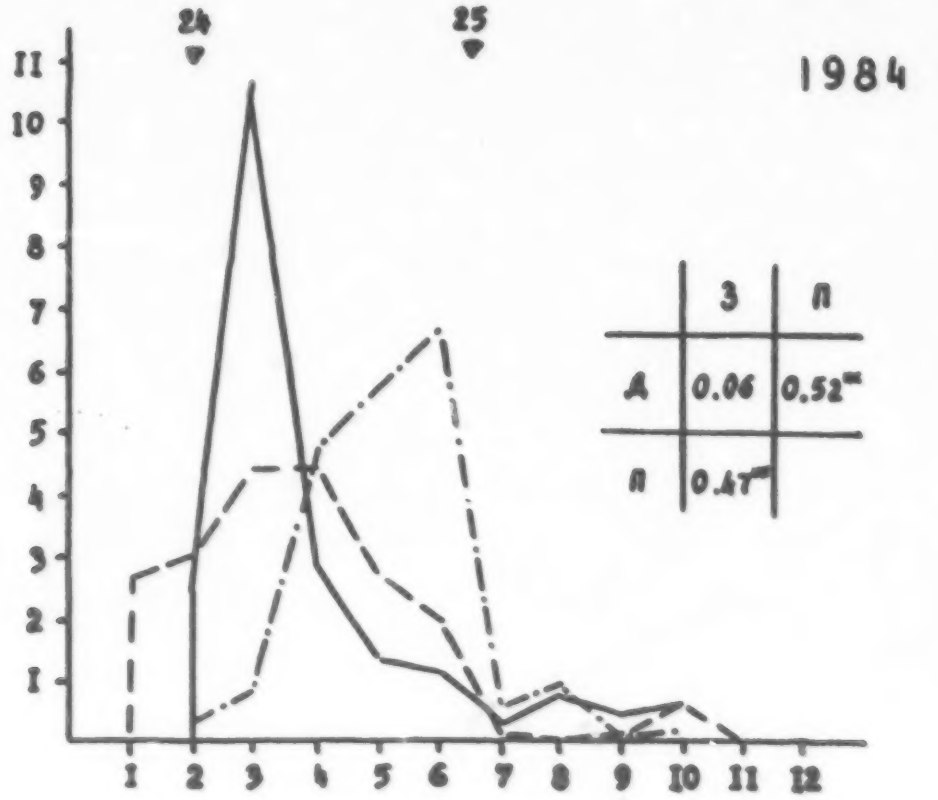


Figure 14. [continued - 1982, 1983]



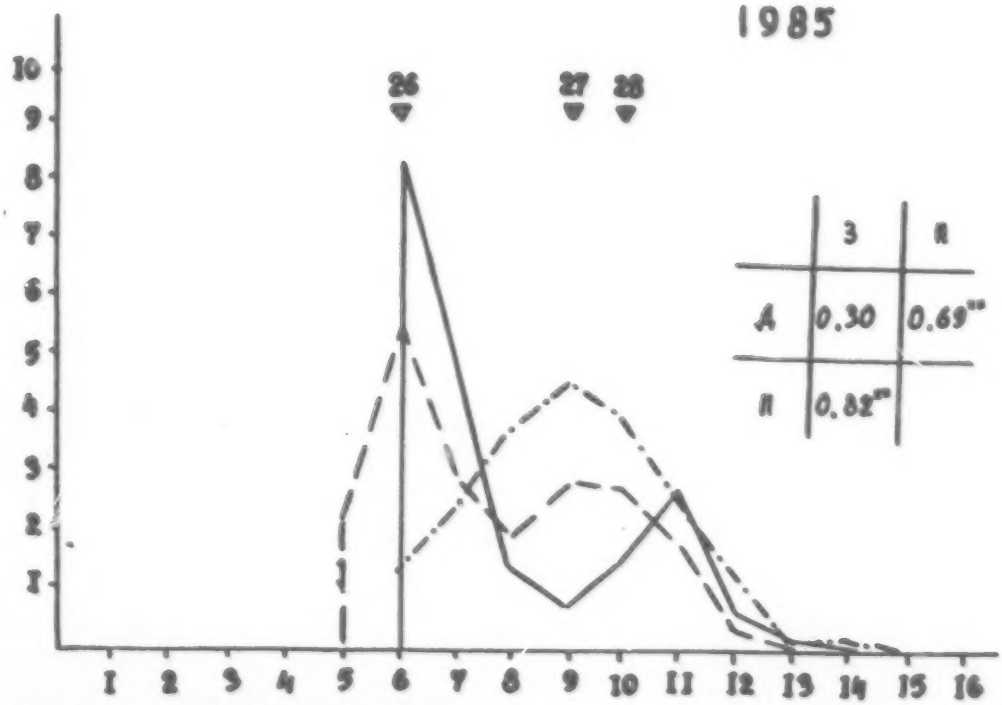


Figure 14. [continued - 1984, 1985]

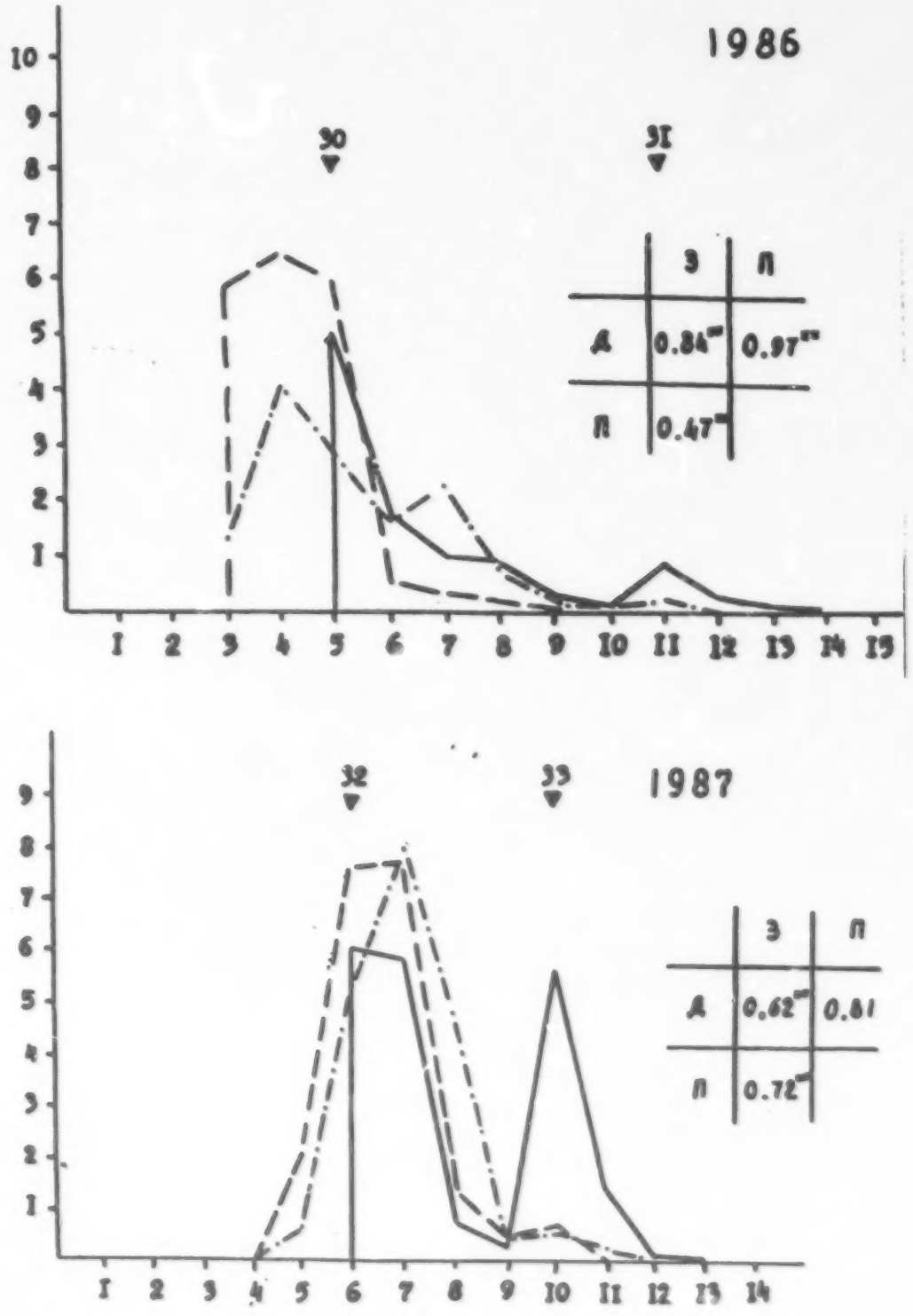


Figure 14. [continued - 1986, 1987]

Table 43

Duration of the migration of overwintered smolts

Year	Duration of total period	"Central" 90% of fish	"Extreme" 10% of fish
1979	43	20 / 46	23 / 54
1980	39	12 / 31	27 / 69
1981	33	27 / 82	6 / 18
1982	47	25 / 53	22 / 47
1983	39	22 / 56	17 / 44
1984	51	25 / 49	26 / 51
1985	41	30 / 73	11 / 27
1986	26	12 / 46	14 / 54
1987	35	18 / 51	17 / 49
Average value	39 ± 2	21 ± 2 / 54 ± 25	18 ± 2 / 46 ± 5

The differences in the duration of the total period of migration of the wild and the overwintered salmon are significant. The ratio of the duration of the migration of the extreme 10% and the central 90% of the smolts in both of the groups under comparison is similar and is close to 1 : 1. The duration of the migration varies strongly from year to year. This value, however, does not depend on the numbers of smolts. The duration of the migration of the central 90% of the smolts is less variable than the total period, but it also does not depend on the numbers of fish.

We will now consider the duration of the migration of the hatchery-reared juvenile fish. For the analysis were utilized the data on the migration of 23 batches of fish.

For the analysis Batches 2 and 3 were combined, since they had been released with an interval of one day, which did not allow us to reliably distinguish the migrants from each of these batches. Batches 15 and 16, which were similar in all characteristics except for the tags, were combined. The following batches were not taken into consideration: Batches 1, 4 and 27, the migration of which lasted for less than 10 days; Batch 7, since the fish of this batch migrated after the completion of the migration of the wild smolts; Batch 14, of which only 6 fish were counted; Batches 22 and 23, since in these batches were released large parr which were resettled practically individually, and Batch 29, released below the FCW. All of the analyzed batches were divided into four groups, released 1.3 km, 3.9 km, 14 km

Table 44

Duration of the migration of hatchery-reared juvenile fish

Batch	Total period	"Central" 90% of fish	"Extreme" 10% of fish
		1.3 km	
2, 3	15	10 / 67	5 / 33
5	11	2 / 18	9 / 82
6	20	16 / 80	4 / 20
8	32	19 / 59	13 / 41
9	57	45 / 79	12 / 21
Average value	27 ± 8	18 ± 7 / 61 ± 11	9 ± 2 / 39 ± 11
		3.9 km	
11	18	4 / 22	14 / 78
19	19	3 / 16	16 / 84
20	13	2 / 15	11 / 85
21	15	5 / 33	10 / 67
Average value	16 ± 1	3 ± 1 / 22 ± 4	13 ± 1 / 78 ± 4
		14 km	
17	23	11 / 48	12 / 52
18	26	12 / 46	14 / 54
24	25	16 / 64	9 / 36
25	18	15 / 83	3 / 17
26	16	11 / 69	5 / 31
28	24	15 / 63	9 / 37
30	29	16 / 55	13 / 45
31	15	10 / 67	5 / 33
32	21	9 / 43	12 / 57
33	17	7 / 41	10 / 59
Average value	21 ± 1	12 ± 1 / 58 ± 4	9 ± 1 / 42 ± 4
		23.5 km	
10	28	11 / 39	17 / 61
12	22	16 / 73	6 / 28
13	22	16 / 73	6 / 28
15, 16	38	9 / 24	29 / 76
Average	28 ±4	13 ± 2 / 52 ± 12	15 ± 5 / 48 ± 12

and 23.5 km above the estuary (Table 44). As can be seen from the Table, the duration of the migration of the hatchery-reared fish was found to be less than for the wild fish, while the distance of the release point did not affect the indices of the duration of migration.

Dynamics of the migration. The intensity of the migration of the juvenile fish over the 10-year period is illustrated in Figure 14. Along the horizontal is shown the time, in five-day intervals, commencing from June 1st. Along the vertical is shown the number of fish migrating per 1 day, expressed as percentages of the total number of fish of the given group that migrated over the total period of the migration. The matrices of the paired correlation coefficients, presented in this same figure, were calculated on the basis of the daily absolute numbers of salmon in each group.

In 1979 the dynamics of the migration of all three groups of fish were not correlated. The peak of the migration of the wild smolts occurred in the 8th five-day period, while that of the overwintered smolts was in the 6th five-day period. The migration of the overwintered fish was more intensive than that of the wild fish. The graph of the migration of the hatchery-reared juvenile fish is represented by a curve with 3 peaks. The first peak coincides with the release of the fish of Batch 8, the second - with the migration maximum of the overwintered smolts, while the third coincides with the release of Batch 9. The absence of a correlation in the intensity of migration of the different groups of fish is apparently connected with the conditions of the release of the hatchery-reared juvenile fish in this and the preceding years. Batch 8 was released 1.3 km from the mouth of the river, at a water temperature of 5°. Wild smolts in the Luven'ga river do not migrate at such a low temperature. In 1978 the releases were made at a distance of 1.3 and 3.9 km. From these releases there remained in the river 18 and 13 thousand fish, respectively. In 1979 the juvenile fish that were released at a distance of 1.3 km could have displaced the overwintered fish that were living in the section from the FCW to 1.3 km from the mouth of the river, and also the wild presmolts that were living there. During the first 10 days after the release of Batch 8 there were counted 40 thousand hatchery-reared fish, 51 overwintered fish and 72 wild fish. During the last 10 days prior to the release of Batch 9 very few fish of the previous batch migrated, not more than 10 specimens per day.

In 1980 a significant correlation was found in the daily numbers of juvenile fish of the wild and overwintered smolts, and also of the overwintered and the hatchery-reared fish.

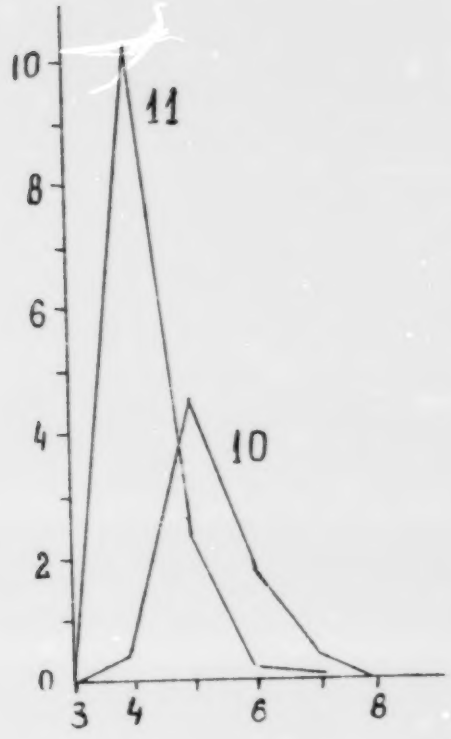


Figure 15. Dynamics of the migration of the downstream-migrants of Batches 10 and 11.

Along the vertical: proportion of fish migrating per day, as a percentage of the number of migrants in the given group; along the horizontal: time, five-day periods.

Рис.15. Динамика миграции локатников партий 10, 11.

По-вертикали: доля рыб, мигрировавших за день, процент от количества мигрантов данной партии, по горизонтали - время, пятидневки.

In Figure 14 it can be seen that the peak of the graph of the migration of the overwintered smolts is located between the [peaks of the[17]] graphs of the hatchery-reared and the wild salmon.

The first hatchery-reared fish were counted only 3 days after the release of Batch 10 at a distance of 23.5 km from the estuary. In contrast, the fish from Batch 11, released 3.5 km from the estuary, were counted in the FCW on the first day. The migration of the fish from both batches proceeded simultaneously, although the fish were tagged and so the dynamics of their migration could be distinguished (Figure 15). In the fish released at 23.5 km the migration was drawn out, while 80% of the fish that migrated after being released at 3.5 km escaped into the sea on the first day.

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17 Omitted in Russian text. [Tr.]

In 1981 Batch 12 was released prior to the beginning of the migration of the wild smolts (Figure 14). Hatchery-reared fish appeared in the FCW 15 days after their release, while the maximum was noted 25 days after the release of this batch. There were only a quarter as many migrants from Batch 13 as from Batch 12, and therefore the second peak, which was due to the migration of the fish from Batch 13, is lower than the first peak.

An interesting pattern was observed in 1982. The dynamics of the migration of the hatchery-reared and the overwintered juvenile fish are strongly correlated, while the migration of the wild smolts is negatively, though not significantly, correlated with the migration of the other two groups. It is possible that this is connected with the fact that batches 14 - 16 were released at a temperature of 5° at a distance of 21.0 - 23.5 km from the estuary. Some individual fish from these batches were counted at the FCW 10 days after the release. In all, from these three batches there were counted 600 fish, the migration of which could not noticeably have an influence on the 6.5 thousand wild smolts. Prior to the day of the peak of the migration of the wild fish only 2 hatchery-reared fish had been caught. At the time of the release of Batch 17, which was done 14 km from the estuary, only 13% out of the total counted number of fish of Batches 14 - 16 had migrated. The maxima of the migration of the fish of batches 14 - 16 and 17 coincided both among themselves as well as with the maximum of the overwintered smolts. It is possible that the release of the hatchery-reared fish into the Middle Luven'ga river provoked the migration of the overwintered fish , from the releases of previous years, which were located there. The wild smolts, a large part of which were confined to the Lower Luven'ga river (see Chapter 2. 1), had almost completed their migration by this time.

In 1983 a release was carried out on June 23rd in the upper reaches of the Upper Luven'ga river (23.5 km), when the migration of the wild and the overwintered smolts was already in progress. Hatchery-reared fish were already counted on the day of the release, but the intensity of their migration increased gradually. The migration peaks coincided for the fish of Batch 18, the wild and the overwintered fish, and they occurred on July 1st. The release of Batches 19 and 20 on the following day at a distance of 3.9 km [from the estuary]

extended the peak on the migration graph, while the release of Batches 21 - 23 formed a second peak. All of the correlation coefficients were high and significant.

In 1984 fish from Batch 24 appeared in the FCW on the second day after their release 14 km from the estuary. By the 8th day 75% of the hatchery-reared juvenile fish of this batch had escaped into the sea. Up until this day a total of 5% of the wild smolts and and 50% of the overwintered smolts had migrated. By the time of the release of Batch 25 the hatchery-reared fish of the preceding batch were already not being recorded. There is no correlation of the migration of the wild and the hatchery-reared fish, but each of these groups separately is correlated with the migration of the overwintered fish.

Almost the same kind of correlation matrix characterizes the following year, 1985. The migration of all three groups of fish is drawn out; the graph of the migration of the wild fish is very gently sloped, while the graphs of the hatchery-reared and overwintered fish have two peaks. The first peak of migration of the overwintered fish coincided with the maximum for the hatchery-reared fish, while the second peak coincided with the maximum for the wild fish. In 1986 and 1987 was noted a similar pattern of the migration dynamics of all three groups of fish: a proximity of the peaks and a significant correlation.

The analysis of the patterns of the migration dynamics of the hatchery-reared, wild and overwintered salmon showed a large variability not only in the form of the graphs but also in their position in time. The last circumstance makes it difficult to generalize and compare the indices of the migration dynamics. We attempted to get rid of these difficulties by changing over from absolute time to relative time. For this purpose we accepted as 100% relative time the duration of the total period of migration of a particular group of fish. Then we calculated the proportion of relative time in which there occurred the migration of 5, 25, 50, 75 and 95% of the fish of this group. Such indices, characterizing the migration of the fish of the same group in different years or else the migration of hatchery-reared fish released at the same distance from the estuary, may be subjected to the usual statistical treatment.

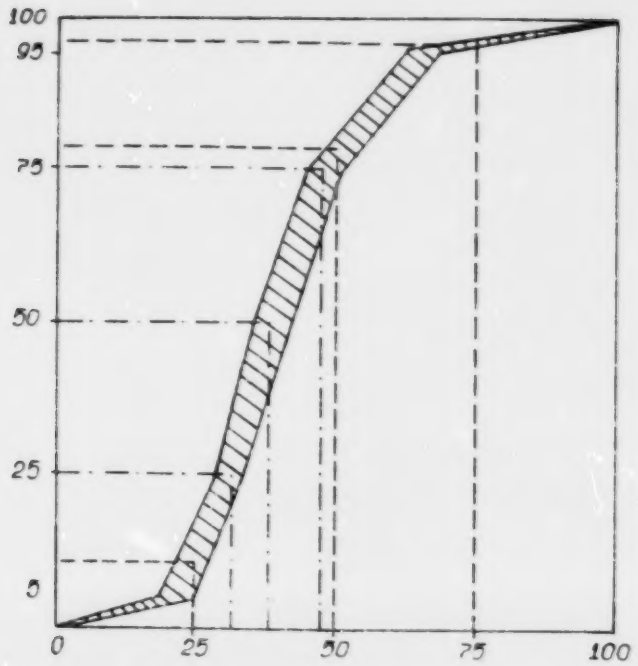

Рис.16. Усредненная динамика миграции диких смолтов.

По вертикали: доля рыб, учтенных от начала миграции, процент от общего количества. По горизонтали: время, процент от общей продолжительности всего периода миграции. Объяснения в тексте.

Figure 16. Averaged dynamics of the migration of wild smolts.

Along the vertical: proportion of fish counted from the beginning of the migration, percentage of total number. Along the horizontal: time, percentage of total duration of the whole period of the migration. Explanations in the text.

The calculated (over a nine year period) dynamics of the migration of the wild smolts are presented in Figure 16 in the form of a cumulative ogival curve (average value ± the error of the average value). The analysis of the curve obtained shows that the migration proceeds very unevenly. 78% of the smolts were counted in the first half of the total period of migration, and 22% in the second half. The unevenness is manifested even more substantially if the period of the migration is divided into four parts (dotted lines[18] in Figure

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[18] Sic. "punktirnye linii". Should surely be here "shtrikovye linii" - "dashed lines", since there are no "dotted lines" in Figure 16. [Tr.]

16). 11% of the fish migrated in the first 25% of the time, 67% in the second quarter, 18% in the third quarter and 4% of the smolts migrated in the last 25% of the time.

If one divides into equal parts the axis on which is indicated the number of smolts migrating from the beginning of the period of migration (dot-and-dash line), then it becomes obvious that the migration of an equal number takes different times at different periods of the migration. The first 25% of the fish migrate in 31% of the relative time, the second in 6%, the next in 10% and the last 25% take 53% of the time; i. e. the migration of 3/4 of all of the smolts took less than 1/2 of the total period of migration.

The averaged dynamics of the migration of the overwintered salmon are similar to that of the wild smolts. Differences are noted only in the time of the migration of the first 5% of the fish, which is shorter in the overwintered smolts (Table 45).

The dynamics of the migration of the downstream migrants that were released close to the mouth of the river (1.3 - 3.9 km) are clearly differentiated from the dynamics of the migration of the wild and the overwintered smolts (Table 45), while the juvenile fish that were released 14 km from the mouth occupy an intermediate position, on the basis of the migration dynamics, between the smolts and the fish released close to the estuary. In the salmon that were released 23.5 km above the estuary the dynamics of the migration are closer to the dynamics of the migration of the wild and the overwintered smolts, than to the dynamics of the hatchery fish released downstream (Table 45).

For greater clarity of the comparison of the migration of the different groups of juvenile fish we will compare the graphs of the intensity of the migration (Figure 17), compiled on the basis of the data in Table 45. For this purpose for each group we determined the relative time spent for the migration of each of six parts, equal to the first 5, 20, 25, 25, 20 and 5%. Dividing the relative number of the juvenile fish (5, 20, 25%) into the corresponding relative time of migration, we obtain the index of the intensity of migration. The graph of the migration of the hatchery fish released close to the estuary ($З_1$ - Z_1) is clearly differentiated from all of the others by the high intensity of migration in the short period after the release and by the non-intensive migration throughout all of the remaining period (Figure 17).

Table 45

Comparative time spent on the migration of juvenile salmon
(percentage of the duration of the total period of migration of the given group)

No. of group	Juvenile fish	Number of migrating fish, %					
		5	25	50	75	95	100
1	Wild (9) *	21.3 ± 2.7 [2,3,4]	31.3 ± 2.8 [3,4]	37.6 ± 2.8 [3,4]	47.3 ± 3.2 [3]	65.0 ± 3.1	100
2	Overwintered (9) *	12.4 ± 2.7 [1,3]	26.2 ± 3.9 [3]	36.9 ± 4.4 [3,4]	48.2 ± 4.2 [3]	65.9 ±4.4	100
3	Hatchery-reared, 1.3 and 3.9 km (9) **	5.8 ± 0.8 [1,2]	7.8 ± 1.8 [1,2,4,5]	9.7 ± 2.4 [1,2,4,5]	19.8 ± 5.3 [1,2,4,5,]	48.9 ± 8.8 [5]	100
4	14 km (10) **	8.9 ± 1.5 [1]	17.1 ± 2.6 [1,3,5]	23.6 ± 3.4 [1,2,3,5]	39.8 ± 4.9 [3]	66.9 ± 4.5	100
5	23.5 km (4) **	23.5 ± 10.5	37.8 ± 7.1 [3,4]	44.5 ± 7.0 [3,4]	58.0 ± 9.8 [3]	75.2 ± 8.6 [3]	100

NOTE. The [superscript] numerals designate the number of the group with which the significance of the difference exceeds 0.95.

* Number of years of observations.

** Number of batches analyzed.

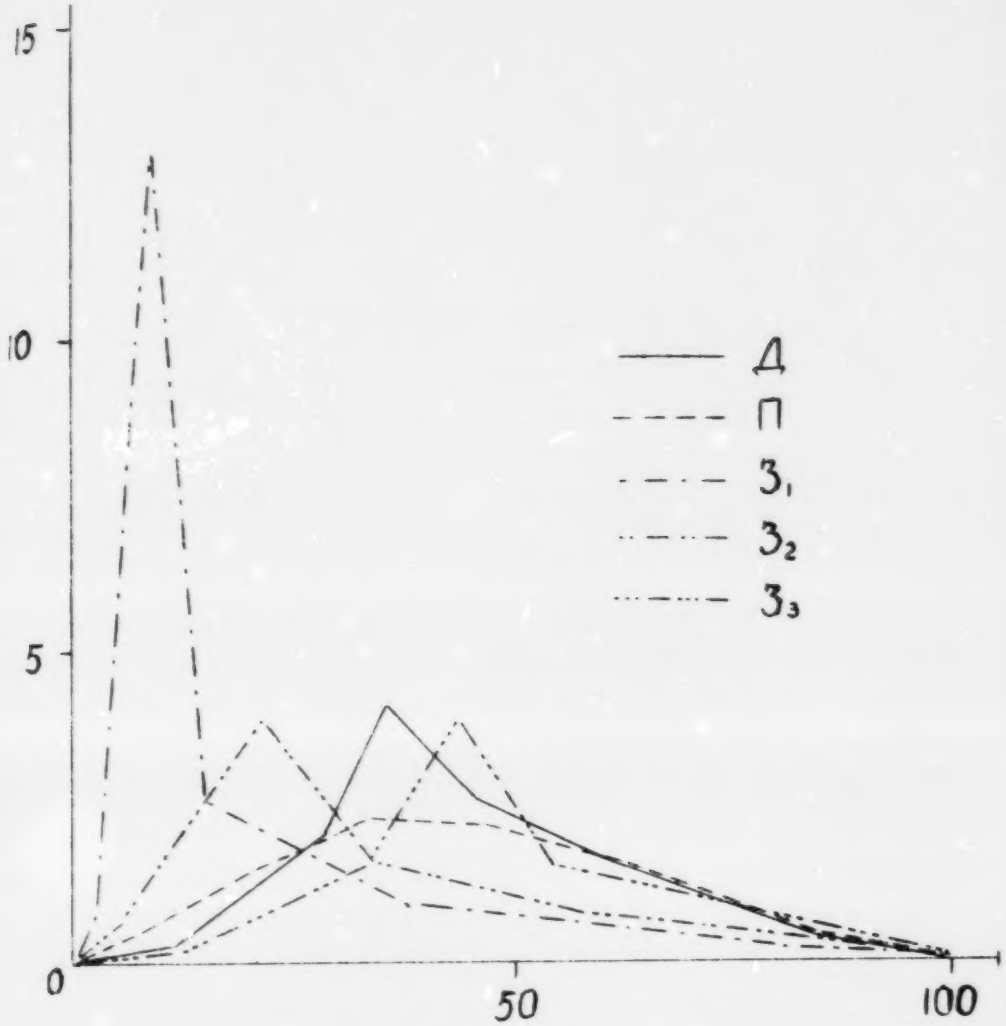

Рис.17. Динамика миграции молоди различных групп. По вертикали: количество мигрантов за единицу времени, %, по горизонтали: время, %, Д - дикие, П - перезимовавшие, $З_1$, $З_2$, $З_3$ - заводские, выпущенные в 1.3-3.9, 14, 23 км, соответственно.

Figure 17. Dynamics of the migration of different groups of juvenile fish. Along the vertical: number of migrants per unit time, %; along the horizontal -time, %; Д - D - wild fish; П - P - overwintered fish; $З_1, З_2, З_3$ - Z_1, Z_2, Z_3 - hatchery-reared fish, released at 1.3 - 3.9, 14 and 23 km, respectively.

In the overwintered fish the maximal intensity of migration is lower than in the other groups of salmon. The graphs of the migration of the other three groups of juvenile fish (hatchery-reared fish released 14 and 23.5 km from the estuary and the wild fish) are differentiated only by the position of the maximum of the migration intensity on the time axis. In the

juvenile fish released at 14 km ($З_2$ - $З_2$) the maximal intensity occurs earlier than in the wild fish, while in the fish released at 23.5 km ($З_3$ - $З_3$) the peak occurs later. The actual form of the graphs of the migration of these three groups of juvenile fish is quite similar.

Consequently, if one considers the dynamics of the migration of the wild juvenile fish as the norm, then the release of the salmon at 14 and 23.5 km normalizes the migration behaviour of the juvenile fish (Figure 17, Table 45). This may be determined by two factors: a selective screening of the parr and the completion of smoltification in the silvery smolts - presmolts.

A selective screening of the parr is corroborated by the results of an analysis on the effect of the conditions of release on the proportion of migrating fish (see Chapter 3. 2). As the test analysis showed, the distance of the release point from the mouth of the river affects the proportion of migrants only in interaction with the dimensions of the released juvenile fish and the date of the release. With an early release far from the mouth of the river the proportion of migrants is found to be high with large juvenile fish and low with small juvenile fish. With an early release close to the mouth of the river the proportion of migrants is uniformly high with both the large and the small juvenile fish: if in the former case the small parr remain in the river, finding a refuge for themselves in the Middle or Lower Luven'ga below the point of release, while the large silvery smolts depart into the sea, then in the latter case the juvenile fish depart into the sea regardless of their size, since the possibilities for remaining in the lower reaches of the river are limited.

In the case of a late release far from the mouth of the river the proportion of migrants is small and does not depend on the size of the fish. This may be explained by the fact that in conditions that are unfavourable for migration not only the small but also the large juvenile fish remain in the river. Consequently, by changing the distance of the point of release from the mouth of the river, we change the conditions for the resettlement of those juvenile fish which at the time of the release are found not to be ready for the transition into the sea. The cause of this lack of readiness lies in the incompleteness of the smoltification of the hatchery-reared juvenile fish. One may judge this on the basis of the activity of the SDH

(succinic dehydrogenase, KF[19] 1.3.88.1) enzyme in the chloride cells of the gill epithelium. The chloride cells play an important role in the osmoregulation of bony fish. In juvenile salmon an increase in the SDH activity of the chloride cells reflects the development of the process of smoltification (Chernitskii, 1979, 1985a; Langdon and Thorpe, 1985). For this reason the SDH activity may serve as a quantitative criterion of smoltification.

Table 46

Succinic dehydrogenase activity in the chloride cells of juvenile salmon, conventional units

Juvenile fish (n)	SDH activity
Parr (52)	38 ± 1
Wild smolts (46)	75 ± 1
Overwintered smolts (38)	73 ± 1
Hatchery-reared silvery smolts at the hatchery (49)	51 ± 1

On the basis of this index the largest silvery smolt, present in the hatchery, occupy an intermediate position between the parr and the smolts, both wild and overwintered (Table 46), which points to an incompleteness in the smoltification process in the hatchery-reared juvenile fish. In the hatchery-reared silvery smolts taken from the FCW the SDH activity was found to be higher than in the fish studied at the hatchery. In comparing the SDH activity in the largest silvery smolts, it is evident that the SDH activity is higher in the fish that have travelled a longer distance along the river, as compared with fish released close to the estuary (Figure 18). An increase in the SDH activity after the release from the fish hatchery and migration along the river was found in juvenile salmon not only from the Kandalaksha fish hatchery but also from the Vygskii hatchery, as well as in juvenile Baltic salmon and Baltic sea trout from the Salatskii hatchery (Loenko and Chernitskii, 1984).

[19] The Russian abbreviation KF is used for creatine phosphate. [Tr.]

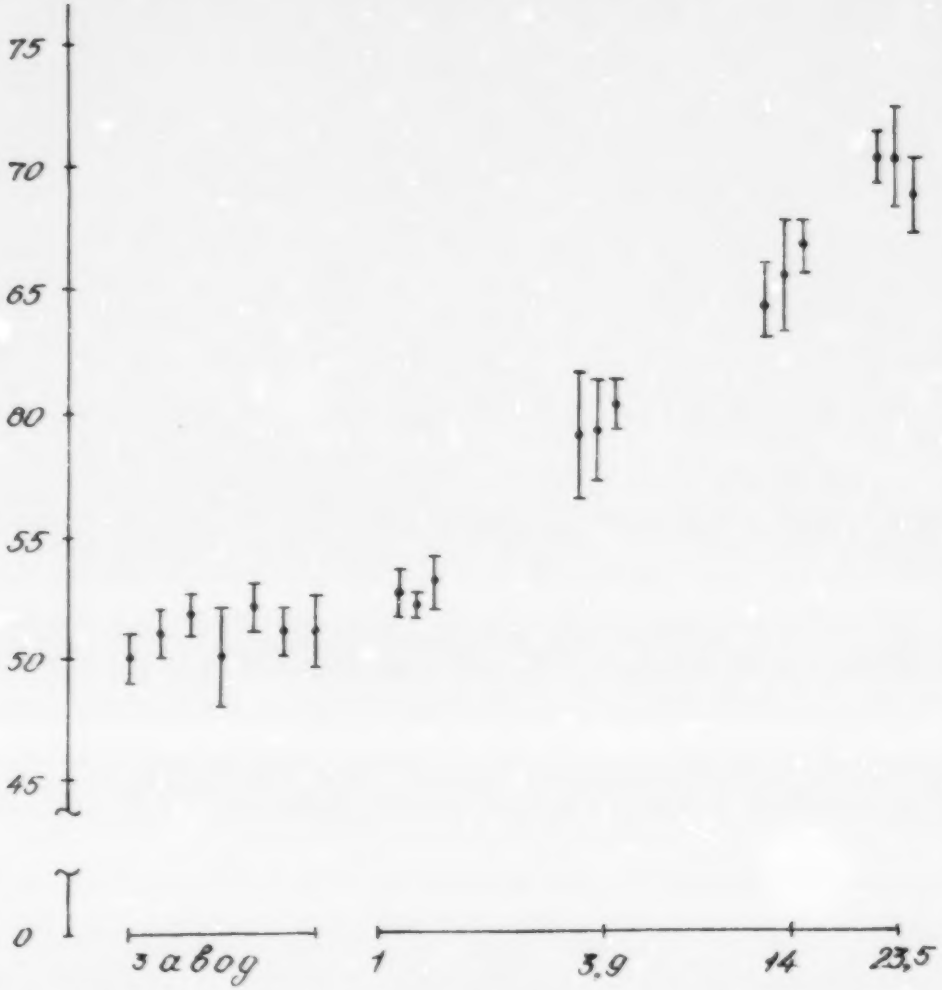

Рис.18. Активность СДГ заводских серебрянок на заводе и после выпуска, $x \pm m$.

По вертикали: активность СДГ, усл. ед., по горизонтали: расстояние от места выпуска до устья реки, км, логарифмическая шкала.

Figure 18. SDH activity of hatchery-reared silvery smolts at the hatchery and after release, $x \pm m$.

Along the vertical: SDH activity, conventional units; along the horizontal: distance from the point of release to the mouth of the river, km, logarithmic scale.

завод - zavod - fish hatchery

Thus, judging by the SDH activity and the dynamics of the migration, the degree of smoltification is greater in the juvenile fish released into the river at a considerable distance

from the estuary than in the juvenile fish maintained in fish hatcheries or released close to the mouth of the river. This phenomenon is a consequence of the complex character of the regulation of smoltification, that is directed to the realization of the migration of the juvenile fish under optimal conditions (Barannikova, 1975). The changes which occur during the process of smoltification prepare the juvenile fish to life in the sea . The physiological state of the smolt is already inadequate to the freshwater conditions (Chernitskii and Shterman, 1981). Consequently, at least some of the smoltification changes should be completed directly prior to the departure from the river into the sea. Since there exists a positive direct and a positive inverse relationship between the processes of smoltification and migration, then not only is smoltification a necessary condition for the transition of the juvenile fish into the migration state, but also the possibility for carrying out the migration may be a condition that is necessary for the completion of smoltification (Chernitskii, 1985b). For attaining the maximal possible degree of smoltification of the hatchery-reared juvenile fish it is necessary to provide the opportunity for the downstream migrants to carry out a fairly extended downstream migration after the release from the hatchery. It has been shown by many investigators that after a sojourn in the river of 20 - 30 days the hatchery-reared downstream migrants become similar to the wild smolts (Mitans, 1970; Shustov, 1983; Bakshtanskii and Nesterov, 1985).

* * *

The comparison of the hatchery-reared and wild salmon revealed differences in all the studied indices. On more than one occasion the dissimilarity has been described of the wild and hatchery-reared juvenile fish with regard to their size, nutritional state, feeding and migrational behaviour, fatigability and susceptibility to narcosis, and haematological and biochemical indices (Bakshtansky et al., 1979; Shustov et al., 1981; Bakshtanskii and Nesterov, 1985; Piggins and Mills, 1985). These differences in large measure determine the high mortality of the of the hatchery-reared juvenile fish under natural conditions. Because of their inability tc oppose the current some of the downstream migrants are

carried out to sea immediately after their release, where they die quickly in the salt water, both due to the unpreparedness of the osmoregulatory system and also due to predatory marine fishes. Those fish that remain in the river do not die immediately. During the summer, apparently, while there is sufficient food present, they may continue to exist. Towards the autumn, however, the food content in the river diminishes and the hatchery-reared parr can not withstand the competition with the wild fish, since they are less agile and, moreover, the wild salmon force out the hatchery-reared fish into less favourable sections, which decreases even more the chances of survival of the latter.

The results obtained by us show that juvenile fish of good quality are encountered among the hatchery production. From the information in the foregoing chapter it is evident that some of the released salmon may survive in the river. The proportion of such overwintered fish is insignificant but on the basis of their qualitative indices they closely resemble the wild smolts. There are also no differences between the overwintered and the wild smolts in their survival in the sea.

At the present time fish culturists have few opportunities for improving the quality of the juvenile fish reared. It is possible, however, to increase the proportion of the quality juvenile fish among the released production. For this purpose it is necessary to select the hatchery-reared fish prior to the release and to take into account a whole series of factors during the release.

Chapter 5. BIOTECHNICAL METHODS FOR INCREASING THE SURVIVAL RATE OF THE HATCHERY-REARED JUVENILE SALMON IN NATURAL CONDITIONS

The survival of the juvenile fish following their release into natural conditions is determined in large measure by their quality, which reflects the whole complex of their rearing conditions in the hatchery. Special methods, however, have also been developed, directed towards facilitating the transition of the young salmon from the hatchery conditions to the natural conditions. Included among these methods is the training of the fish during the rearing process, the selection of the fish prior to the release and the release itself.

5. 1. Training of juvenile fish

Apparently, one of the first attempts to prepare hatchery-reared juvenile fish for life in natural conditions was a training with the application of predators (fish, birds and conventional models). Presentation of the predators was accompanied by the effect of an electric current or another intimidating stimulus. Detailed information on such studies are included in the monograph by Leshcheva and Zhuikov (1989). However, according to the data of Norwegian specialists, the training of juvenile salmon with the use of live cod did not affect the return (L. P. Hansen, Norsk Institutt for Naturforkning, personal communication 1. 11. 89). This may be explained by the fact that the defensive conditioned reflexes in juvenile fish are unstable and they decay rapidly when there is no reinforcement (Leshcheva and Zhuikov, 1989).

The study of the fate of hatchery-reared salmon in natural conditions has shown that the misfortune of these fish lies not only in that they do not know whom to beware of, but also that they do not know how to find food and secure biotopes, and even simply how to swim.

For this reason, some elements that promote the adaptation of the fish to a broader complex of natural factors have started to be included in the preparation of the juvenile fish.

One of the well documented and long criticized (by fish-breeders themselves) differences between the hatchery conditions and the natural conditions is the low rate of water exchange in the fish-breeding installations and, associated with this, the low velocity of the current and the weak physical conditioning of the hatchery-reared juvenile fish. For this reason an augmentation of the current velocity began to be utilized to improve the quality of the hatchery-reared juvenile fish. Data indicating that fish trained in a strong current produce a better return than untrained fish appeared quite some time ago (Wendt and Saunders, 1973). One of the causes of the positive effect of a high current velocity was disclosed in the studies of Youngson and his co-authors. (1986, 1989). They showed that an activation of the thyroid system of the fish occurred when the pre-smolts of Atlantic salmon were held in high velocity conditions. It was found that holding the fish in a strong current provides the same effect as an injection of thyroxine into smolts: migration is prolonged and fewer of the released fish roll down into the sea in the first hours following the release.

This same principle was incorporated in the training system for the juvenile fish that was proposed by research workers in the Institute of Biology of the Karelian Branch of the Academy of Sciences of the USSR (Shchurov et al., 1986 a, b). By increasing the water supply into the tanks and changing the direction of the stream of delivered water, they raised the current velocity from 0.1 - 0.2 m/s to 0.4 - 0.6 m/s. An automatic feeder delivered the feed in small portions every two minutes into that part of the tank with the highest flow, and therefore the fish in the tank were forced to plunge into the strong current to get food. After 1.5 months the salmon that were held in the experimental tank were found to be twice as hardy as the controls. The differences between the trained and the untrained fish were manifested immediately after the release (Shchurov et al., 1986 b). The control fish were carried out of the river during the first two days, while the trained fish remained in the river in large numbers. Analyses that were carried out on the following day showed that the feeding

intensity was higher in the trained fish than in the controls. Apparently the feeding reaction to mobile food is better developed in the trained juvenile fish.

A deficiency of this training method is the separating out of a group of the most active dominant individuals, which suppress the growth and development of the remaining fish in the rearing installations (Safonov et al., 1988). Moreover, L. P. Hansen, who has already been mentioned, cited some data that in Norway the rearing of salmon at high current velocities has not increased the return of the adult fish.

The problem of the training of the juvenile fish has been resolved in a different way by means of the "*Turnir*"[20] apparatus (Safonov et al., 1988; Leshcheva and Zhuikov, 1989), in which a circular current of water rotates a vane, bringing into operation a food dispenser that is connected with it. The vane periodically moves the juvenile fish away from the place where the feed is continuously and automatically supplied into a water current with a velocity of 30 - 40 cm/s. Other fish then occupy the vacated feeding territory. The application of the "*Turnir*" increases the locomotory activity of the fish and their physical conditioning, levels out the dominant-subordinate relationships of the juvenile fish, and enriches the habitat of the young salmon with visual, tactile and hydrodynamic stimuli.

Nevertheless, whatever the holding conditions, the juvenile fish will vary in their quality. Thus, even among the progeny of one and the same pair of spawners, the onset of smoltification will differ by 1 - 2 years (Thorpe et al., 1980). This determines the necessity for sorting the juvenile fish prior to release.

5.2. Selection of juvenile fish for release

The changes which occur during smoltification affect practically all of the studied indices (see Chernitskii, 1983; Higgins, 1985), although it is very difficult to pick out reliable criteria of smoltification. A fundamental requirement for such indices is the specificity of their relationship with the process of smoltification.

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[20] The translation of the Russian word "turnir" is "tournament". [Tr.]

The features, which change in an orderly fashion during the smoltification of wild juvenile fish, do not always indicate the smoltification of juvenile fish that have been reared in fish hatcheries. It has been shown, for example, that silvering (the replacement of the melanin pigmentation in the integument of the juvenile fish by guanine pigmentation), which is the most noticeable external manifestation of smoltification of the wild juvenile fish, is not always indicative of smoltification in hatchery-reared juvenile fish (Wedemeyer et al., 1980; Chernitskii, 1983). For this reason an index that is selected as a criterion of smoltification should directly reflect the changes of some vitally important system.

The most graphic index of the preparedness of the juvenile fish to the transition into the sea is the appearance of symptoms of migratory behaviour. This is a clear-cut criterion (Brannon et al., 1982) but it is a complicated matter to utilize it in practice, since one needs to have special tanks and also particular combinations of abiotic factors, which regulate the migration of the smolts, in order that migratory behaviour may be displayed by juvenile fish under hatchery conditions (Loenko and Chernitskii, 1986).

A group of ichthyologists in the USA (Gorbman et al., 1982) proposed a whole complex of morphological indices (state of the teeth, of the integument in the region of the anal opening and around the anal fin, scale structure, pigmentation of the body and of the fins), on the basis of which they divided the process of the transition from parr to smolt into several stages. It remains unexplained, however, as to how closely the changes in these features are associated with smoltification. This same question arises also with regard to the indices proposed as criteria of smoltification by researchers in the *GosNIORKh* [State Scientific Research Institute of Lake and River Fisheries] (Kazakov and Minina, 1984; Kazakov and Kozlov, 1985): the light-reflecting capacity and the biochemical properties of the skin.

Tests for salt tolerance are very instructive, but by itself the capacity of the juvenile salmon to survive in sea water is not a reliable criterion of smoltification, since in several species the salt tolerance begins to increase earlier than the smoltification is completed. At the same time the mechanisms of the salt tolerance of parr and of smolts are different in principle. For this reason , as a test of smoltification it was proposed to determine the capacity of

the fish to survive in water of a very high salinity - 40‰ (Wedemeyer et al., 1980). Such a procedure allows one to distinguish the growth in salt tolerance associated with the increase in size of the fish from the growth in salt tolerance brought about by smoltification (Saunders et al., 1985). However, if the fish are tested in water of 35‰ salinity, then it is necessary to measure the concentration of sodium in the blood of the fish (Clarke, 1982). Juvenile fish in which the sodium concentration does not exceed 170 milliequivalents per liter, after a sojourn of 24 hours in such a medium, are considered as smolts, while if this concentration is found to be higher then these fish are not yet smolts.

Besides these methods, requiring sea water of high salinity and the expenditure of time for conducting the experiments, there are also widely utilized tests that allow one to make a judgement concerning the state of individual elements of the system that regulates the water-salt exchange, mainly - of the chloride cells. One may evaluate the development of smoltification on the basis of the increase in activity within these cells of the enzymes that are connected with the transport of sodium: succinic dehydrogenase - SDH and adenosine triphosphatase - ATPase (Chernityskii, 1979; Boeuf et al., 1985).

In recent years, thanks to the development of analytical techniques, and in the first instance - of instruments and methods of radioimmunological analysis, it has become possible to evaluate the change in the state of the endocrine system, which plays an important role in the development of smoltification. It has been shown that with smoltification there occurs an increase in the blood of the hormones of the thyroid gland - thyroxine (T_4) and of the interrenal gland - cortisol (Virtanen and Soivio, 1985).

Most reliable is considered to be the evaluation of smoltification directly on the basis of several features, pertaining to smoltification changes of various levels, for example: 1 - a test for the capacity for preserving the stability of the sodium level in the blood with a transfer into sea water, 2 - an evaluation of the enzyme activity in the chloride cells of the gill epithelium, 3 - an evaluation of the thyroxine level in the blood (Dickhoff et al., 1985). Unfortunately, all these methods allow one to evaluate the state of the fish only post mortem. Furthermore, the technical complexity of most of them permits only a selective evaluation on a small

number of juvenile fish, and they are employed only for research purposes. By their means evaluations are made of the state of juvenile fish, reared not in normal conditions but rather in such conditions in which the fish develop more rapidly. These tests are widely utilized in studies of the effect of various influences on the salt tolerance of the juvenile fish.

It is necessary for practicing fish breeders to evaluate the state of all the fish intended for growth in the sea, and to carry out such evaluations repeatedly, since smoltification proceeds unevenly, even in fish originating from the same parents; it is necessary to pick out the juvenile fish, that are maximally prepared for the transition from fresh into sea water, from one and the same batch, several times during the spring-summer period. Most suitable for such purposes are methods based on the selection of salt water by the smolts. In Figure 19 is shown a schematic diagram of a Norwegian device for separating juvenile fish in a salinity gradient: two round plastic tanks, A and B, are connected by a wooden channel lined with a polyethylene film. Diameter of tank 2 m, depth 1 m, length of channel 16 m, width 40 cm, depth 30 cm. Freshwater enters tank A and passes from here along the channel into tank B, and from the latter is discharged into the drainage system. Sea water (30‰) is brought in to the channel at five different points, and in this manner the salinity of the water in the channel and in tank B is increased to 17‰. In Figure 20 is shown the result of the testing of a large group of hatchery-reared juvenile fish (more than 400 specimens). As can be seen from the Figure, the distribution of the fish in the salinity gradient is clearly associated with the manifestation of the external features of smoltification. It is evident that the salinity of the water in tank B may be increased by increasing the volume of the sea water added. The creation of such uncomplicated devices allows one to make rapid, repeated, *in vivo* selections, from the reared juvenile fish, of those individuals which at a given moment have attained a state of readiness for life in the sea. A fundamental obstacle, standing in the way of the introduction of the gradient sorting system into practical fish-breeding and hatchery operations in our country, is the absence of sea water of high salinity close to the existing hatcheries. For this reason in the construction of new salmon hatcheries it is necessary to plan for the supply not only of freshwater but also of sea water.

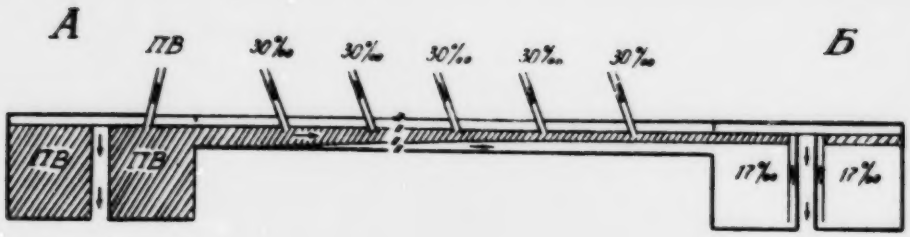

Рис.19. Схема разделительного устройства.
ПВ - пресная вода (Knutsson, Holm, 1977).

Figure 19. Schematic diagram of a separating device.
IIB - PV - fresh water (Knutsson and Holm, 1977).

For the present however, as in the Sixties, when work was started on the rearing of smolts in fish hatcheries, the juvenile fish are selected on the basis of the external features of smoltification and on the basis of the body weight that is characteristic of smolts of a given species. Thus, in Norway in one of the leading aquaculture firms, "Sea Farms A/S", the selection of the smolts is made in April, May and June (and sometimes even in July), when in the juvenile salmon weighing 25 - 30 g or more there appear distinct changes in the coloration and, in part, in the proportions of the body: the parr bands disappear, the dorsal part darkens, the ventral part becomes silvery and the fish become elongate. These changes are associated with the increase in temperature, the elongation of the daylight hours and the increase in the dimensions of the fish (10 - 15-gram smolts are very rarely encountered).

In our hatcheries that are rearing smolts the readiness of the juvenile fish for transition into the sea is evaluated visually. Other factors are also taken into consideration, such as, for example, the difference in temperature between the freshwater and the sea water (K. O. Jrgensen[21], "Sea Farm", personal communication, 12, 11, 86). It seems that the Norwegian fish-breeders have returned to a visual evaluation of the degree of smoltification at a new level of the biotechnology of smolt rearing, which guarantees that in the spring - summer period the juvenile fish of a particular size and form are smolts. Even the best selected juvenile fish, however, may be lost with a poor organization of the release.

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[21] Sic. probably Jorgensen. [Tr.]

5. 3. Variants in the organization of the release

The principal production of salmon hatcheries at the present time comprises smolts, although some of the fish both in Europe as well as in America are released at the parr stage.

Advantages and drawbacks of rearing juvenile fish to the smolt and the parr stage for the purpose of restoring stocks of the Atlantic salmon (after Alexander and Galbraith, 1982, with modifications):

Smolts	Parr
Advantages	
Decrease in the amount of eggs required.	Moderate cost of production.
Good opportunities for breeding.	Good natural selection in the river.
Number of smolts reaching the sea is known.	Good opportunities for breeding.
Opportunity to carry out tagging at the hatchery.	Reasonable size of gene pool.
Low cost and labour intensity in the re-settlement of the fish.	
Drawbacks	
High cost of production.	Necessity for resettlement on release, requiring expenditure.
Decrease of natural selection in the river, leading to increased mortality in the sea.	Necessity for monitoring to determine the survival rate in the river and the numbers of smolts.
Increased risk of epizootics because of the extension of the rearing time.	Extension of time of waiting for the return.

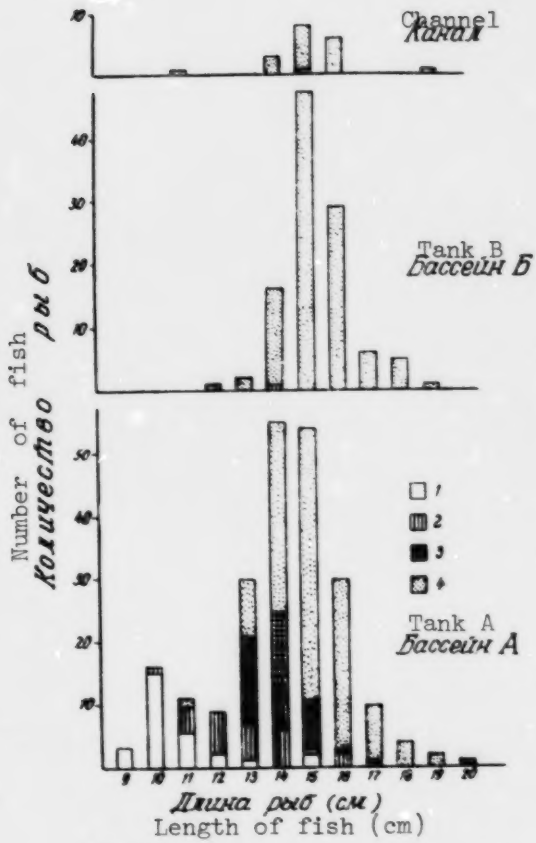

Figure 20.

Distribution of fish in the separating device.

1 - parr, 2 - silvery parr, 3 - almost silvery smolt, 4 - silvery smolt (Knutsson and Holm, 1977)

Рис.20. Распределение рыб в разделительном устройстве.

1 - пестрятки, 2 - серебристые пестрятки, 3 - почти серебрянки, 4 - серебрянки (Knutsson, Holm, 1977).

5.3.1. Release of parr

The methodology for the release of parr was developed a long time ago. The fundamental principles for the release of parr were established by Otterström (1938). The contemporary requirements for the release of parr are as follows: the released parr should be resettled as widely as possible along the river system, so as to make use of the entire productivity of the river; the dimensions of the parr should correspond to the summer depth of the given river; the numbers of fish released should be calculated in accordance with the acceptance capacity of the area of water, taking into account the salmon already living in the river (Rasmussen, 1984).

As has been shown by direct underwater observations, the death of parr that were released in breach of these requirements was caused mainly by predatory fishes (Legault and Lalancette, 1987). The authors of the last study proposed that, in order to increase the survival of the juvenile fish, provision be made for the possibility of providing a rest for the transported fish prior to their release, and, mainly, that the salmon be resettled as widely as possible. The survival of the hatchery-reared parr is negatively affected by the presence of wild juvenile fish at the release site. Our observations showed that in this case the wild salmon force out the hatchery-reared salmon into less suitable sections.

It is a complicated matter to accomplish the resettlement of parr for technical reasons, in the first instance - because of the lack of transportation. The presently used means are not adapted for the release of parr. The live-fish trucks can release juvenile fish only in those sections of the river to which there are approach driveways. Floatplanes also may put down only on limited sections of the area of water, and moreover these sections are not very suitable for habitation by the parr, since they are plës[22] sections rather than riffles. Helicopters make use of a larger number of sections for landings, but also by no means all, and moreover the application of helicopters increases the cost of production of the hatchery-reared juvenile fish.

In Canada fire-fighting helicopters of the forest protection service, which have external water tanks with a capacity of 416 liters, are used for the resettlement of parr. At the release site the helicopter hovers several centimeters above the water and empties the tank. The absence of aeration of the water limits the time of transportation to 10 - 15 min (Semple and Mercer, 1987). Water transportation is rarely employed for the release and resettlement of juveniles of the Atlantic salmon, since typical salmon rivers are small and have rapids.

Thus, the resettlement of the juvenile fish in small batches, taking into account the acceptance capacity of the section of the river, can not be provided for with the means of transport that are now employed. For the optimal release of the fish it is necessary to have transportation that can move along the river, overcoming shoals, rapids, aquatic vegetation,

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[22] For "plës" see footnote 7 on page 19 of this translation. [Tr.]

sunken logs and sections with a vigorous flow. The hovercraft meets such requirements (Levina et al., 1990). Thus, an operation trial of the "Bars" hovercraft on the Pinega river showed that this modern vessel is distinguished on account of its structural features (renunciation of aircraft propellers and provision for a complete separation from the supporting surface) from the previously used models by the lower level of the effect on the environment. The complete separation from the supporting surface allows the hovercraft to overcome shoals and sandy spits, floating logs, thickets of taller aquatic vegetation, and, when necessary, to come out onto the shore, in particular, for loading and unloading.

A hovercraft intended for the release of juvenile fish should, in our opinion, appear as follows: load capacity of hovercraft 0.5 - 1 x 10^3 kg; cargo compartment made in the form of an aerated tank, divided into several sections which have charging and discharging hatch openings. The juvenile fish are loaded into the tank either directly at the fish hatchery or from other live-fish transportation facilities. After loading, the hovercraft should proceed at a low velocity, which would ensure a minimal effect on the littoral and fluvial biocoenoses. On sections that are suitable for resettlement, the juvenile fish from a compartment are released either directly into the river or, to relieve transportation stress, into adaptational holding nets. After that the hovercraft moves on further, to the next rearing section of the river, where the next portion of juvenile fish is released.

5. 3. 2. Release of smolts

At the present time several variants are employed for the release of smolts, each of which has its merits and drawbacks. In a fairly conventional fashion the known methods of release may be divided into the following groups.

Direct release. If the fish-hatchery installations have their own water discharge into the river, then the reared juvenile fish may be released by raising the barriers in the water discharge array. In order that juvenile fish do not linger in the pipes, it is recommended that rubber balls, of a size somewhat smaller than the diameter of the pipes, be sent down after

the fish (Peterson et al., 1972). Direct release is employed at the Kandalaksha fish hatchery with the release of juvenile fish from the pond into the Niva river (Chernitskii et al., 1989). The pond is equipped with an outlet gutter, installed at the normal retention level. For the release of the fish the water level was raised by 30 cm with the outlet closed, and then the outlet was opened. The juvenile fish that were ready for the transition into the sea could leave together with the upper layer of water that was pouring out. The discharge of the water lasted for about 5 hours. A similar procedure was repeated daily over the course of several days. The released fish got into the old river bed of the Niva.

Advantages: the juvenile fish are neither stressed nor traumatized during the catching and transportation.

Drawbacks: it is imperative that provision be made for the possibility of direct release during the construction of the hatchery, and that the river, alongside which the hatchery is situated, remains suitable for habitation by the juvenile fish.

Release from conveyances. The most widespread variant. At the hatchery the fish are loaded into a live-fish truck, helicopter or aeroplane, conveyed to the river and released directly into the river. The selection of the site of release is determined in the first instance by the requirements presented by the means of transportation: the proximity of roads – for the truck, a landing area suitable for putting down – for the helicopter, and a sufficiently large area of water - for the floatplane.

Advantages: cheap, does not require engineering preparatory work to the body of water in which the release is made. Allows one to utilize a large number of rivers for the release.

Drawbacks: the fish released from conveyances are stressed. Some of the fish die immediately after the release, directly in the river, and some die in the sea, where they are carried passively by the current.

The appearance in the river of a large number of hatchery-reared fish, the "salvo downstream migration"[23] induces a premature migration of the wild smolts (Bakstansky et

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[23] Literal translation of Russian term "*zalpovyi skat*". [Tr.]

al., 1979; Ermolaev, 1988). G. I. Ermolaev has proposed that this occurs because the wild smolts imitate the hatchery-reared smolts, but our observations have shown that provocation to downstream migration plays a smaller role than simply the downstream displacement of the wild fish by the numerous hatchery-reared fish. Batches 1 - 13, 15 - 17, 19 - 23, 25, and 26 (see Figure 4), mentioned in the present study, were released from conveyances. The analysis of the results of these releases has shown that some drawbacks that are inherent to this release variant may be compensated for by increasing the distance from the mouth of the river to the release site. Thus, with the release at 14 and 23 km the effect of the "salvo downstream migration" is manifested more weakly than with the release at 1.5 and 3 km (see Chapter 4. 5) in the first instance because the hatchery-reared fish gain time for adaptation and space for resettlement.

Early release. This is differentiated from the preceding type by the fact that the juvenile fish are released into the river deliberately prior to the time of the migration of the wild smolts. Thus, according to the 1979 Instructions the release should be carried out 2 - 3 weeks prior to the start of the period of the natural downstream migration (Yandovskaya et al., 1979). Research workers of the Institute of Biology of the Karelian Branch of the Academy of Sciences of the USSR have recommended a early release to the Vygskii fish hatchery: prior to the beginning of the high water (winter low-water level of river), before the start of the intensive feeding of the pike and before the arrival of the gulls and terns; from the moment of the break-up of the rapids (Smirnov et al., 1987, p. 77).

Advantages: with the release of juvenile fish prior to the downstream migration a positive effect will be achieved owing to the fact that the adaptation of the hatchery-reared juvenile fish to the natural conditions will be completed prior to the start of their migration (Petrenko, 1976, 1980). Furthermore, the early release guarantees that the fish will fall into the migration window.

Drawbacks: with an early release the juvenile fish have to feed in the river and, consequently, it is necessary to release the fish in small batches, i.e. to resettle them, like the parr.

Separate release. Lying at the basis of this variant is the notion that the released juvenile fish are by no means homogeneous in the degree of smoltification and, consequently, it is necessary to sort the fish prior to their release and to release each group on its own. "The release of downstream-migrant juvenile fish (silvery smolt) and of juvenile fish close to downstream migration (silvery parr 2, 3) is carried out in sections of the river near the estuary at a count of 10 - 15 fish per 100 m^2 area. Juvenile fish with less intensive silvering (silvery parr 1, juveniles with symptoms of silvering) are released into the lower reaches of the river at a count of 5 - 7 fish per 100 m^2 area" (Yandovskaya et al., 1979, p. 80).

According to the data of Bugaev et al. (1987), separate release has given good results on the Keret' river (Karelia), to where the Vygskii fish hatchery takes its production. The juvenile fish for release were divided on the basis of their mass into three categories: fish of mass less than 18 g were released in the upper reaches (40 - 50 km from the estuary), 18-gram fish - in the middle part (20 - 30 km from the estuary), and those weighing more than 18 g - in the lower reaches (5 - 10 km from the estuary). Observations on the migration of the released fish have permitted conclusions to be made on the successful adaptation of hatchery-reared juvenile fish to the conditions in the river with separate release. The effectiveness of this release variant is corroborated by the analysis of the return of the hatchery-reared fish into the Keret' (Smirnov et al., 1987).

Advantages: this resolves the problem of the parr and allows us to make fuller use of the growth areas of the river.

Drawbacks: the necessity for sorting the fish before release and technical problems of resettlement.

Release by way of release ponds. The release ponds are constructed alongside the river, on its lower reaches. The pond is connected with the river bed by two channels, which ensures a flow-through of the water and a synchronism of the changes in the abiotic conditions in the river and in the pond. The juvenile fish are placed in such ponds 2 - 4 weeks prior to the proposed release; they are fed and protected from predators. Closer to

the proposed time of the migration the outlet from the pond was opened and the juvenile fish can go out freely into the river and migrate into the sea. It is assumed that the departure of the juvenile fish from the pond occurs prior to the completion of the process of smoltification and during the most favourable environmental conditions (Harris, 1978). Four years of observations on salmon pre-smolts that had been placed in ponds, which were carried out in the USA (Rottiers et al., 1988), have confirmed that the migration of the hatchery-reared juvenile fish from the pond is determined by the same factors as the migration of the wild smolts: temperature, intensity of illumination and time of day. For example, with the opening of the pond on May 1st 82% of the fish migrated in 23 days, while with the opening on May 19th 98% migrated (Kennedy et al., 1984). Experiments carried out in Iceland have shown that with the release of the juvenile fish by way of ponds the return is increased more than twofold, as compared with the return from a release from conveyances (Isaksson et al., 1978).

Advantages: it is no longer necessary to transport the fish in the last stages of smoltification, that are most sensitive to unfavourable influences. Smoltification is accomplished in conditions that are close to natural, which makes it easier for the fish to fall into the migration window.

Drawbacks: not all the fish leave the release pond, since the juvenile fish in which smoltification did not occur remain in the pond. These fish had to be either recovered by nets or poured off together with the water, by draining the pond. The chances for survival are small for the parr remaining in the lower reaches of the river.

Release through adaptation holding nets. The holding nets are set up in the river itself, in places that are accessible to the transportation carrying the juvenile fish. The juvenile fish rest in such holding nets after transportation and become adapted to the abiotic conditions in the river of release. It is necessary to feed the fish with granular food, but available also to them is the drifting material that passes through the holding net. The release from the holding net may be carried out in a fractional manner, in small groups. Batches 14, 18, 24, 26 and 28 - 33 were released by us in this manner.

Advantages: the transportation of the fish may be done in large batches, while the release is done in small batches. The concluding stage of smoltification occur in the river, in natural conditions, which promotes the full value of this process and the memorization of the smell of the river of release. As a result there is an increase in the return from the juvenile fish that departed into the sea in the year of their release (see Chapter 3. 4).

Drawbacks: technical complications and the necessity for organizing a fish-breeding station.

Direct release into the sea. The first successful release of smolts directly into the Baltic Sea, rather than into a river, was made by Carlin (1955). In 1966 K. G.[24] Pyefinch showed, from tagging results, that the return from a release into the sea was higher than from a release into a river (Pyefinch, 1966). This has been subsequently corroborated on more than one occasion. In north-eastern Norway (Gunnerod et al., 1988) from 1973 to 1983 second-year smolts were released from the Lundamo fish hatchery into the Surna river (20 km above the estuary), into the fjord directly near the shore and into the open sea 100 km from the estuary. The size of the smolts ranged from 13 to 33 cm (average 17.2 cm) and the times of the release coincided with the period of the migration of the wild juvenile fish. The fish that were transported to the sea were gradually adapted to sea water during the process of transportation. The releases of the fish into the river, fjord and sea were carried out simultaneously. The average return, over many years, in the river and inshore catch comprised: 3.0% of all of the released juvenile fish, 1.9% of the fish released in the river, 3.1% of those released in the fjord, and 4.0% of those released in the sea. The differences between the values of the return from the different release variants are significant.

Advantages: the absence of the stage of the river and estuary migration decreases the loss inflicted to the smolts by predatory fishes, both fluvial and marine. It has been shown that pike destroy from 30 to 70% of hatchery-reared smolts in the river (Bugaev et al., 1986). Even burbot consume more than 30% of hatchery-reared downstream migrants

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[24] Sic. In the bibliography, however, these initials are given as K. A. [Tr.]

(Larsson and Larsson, 1975). In the estuary cod and pollock destroy 20 - 25% of the smolts (Hvidsten and Mokkelgjerd, 1987; Hvidsten and Lund, 1988).

Drawbacks: with the release of juvenile fish directly into salt water, the fish in which the process of smoltification has not been completed die. The omission of the stage of river migration does not allow the smolts to memorize the smell of the water in the river of release, and for this reason they do not return into this river. The number of wandering fish increases.

Release into the sea with towing along the river. The juvenile fish are placed into a holding net, which is towed along the river and opened out in the open sea. Preliminary results on the use of this method are promising: the return was found to be twice as high as with a release into the river (Larsson and Larsson, 1979, cited according to Johansson, 1981).

Advantages: the juvenile fish are protected from the predatory fishes; with the towing along the river there is an increase in the probability of the memorization of the smell of the river, which is necessary for an accurate return.

Drawbacks: technical complexity; specific requirements to the river.

Release into the sea with adaptation in ponds. The adaptation ponds are provided with both sea water and with freshwater, which permits a regulation of the salinity of the water in these ponds. The juvenile fish may therefore be gradually adapted to the salt water. Such ponds are present in fish hatcheries in Iceland (Isaksson et al., 1978) and in our country on the White Sea. The use of these ponds in the Knyazhegubskii fish hatchery has allowed the proportion of silvery smolt to be increased 4 - 10 times among the released juvenile fish (Loenko et al., 1987).

Advantages: opportunity for gradual adaptation to the salinity.

Drawbacks: high cost and technical complexity of installation.

Release into the sea with adaptation in holding nets. The juvenile fish are transported in holding nets set up in the sea, where the fish adapt to the sea water in protected conditions. The release from the holding nets occurs during the period of the natural

migration of the smolts. This method has been used in Canada (Sutterlin et al., 1982), in Iceland (Isaksson and Oskarsson, 1986) and in Norway (Jenssen, 1979). In the Faeroes smolts 14 - 16 cm in length were transported from the fish hatchery to the holding net in the sea along a special pipeline (Reinert, 1982).

Advantages: the mortality of the juvenile fish due to river and estuary predators is decreased. The fish gain the opportunity to calm down after transportation. The adaptation of the juvenile fish to sea water occurs in protected conditions. This decreases the mortality from marine predators. Besides this, the processes of desmoltification are retarded in sea water (Chernitskii, 1985 a), which permits a levelling out of the degree of smoltification for the whole group. Thus, juvenile fish which were adapted for 2 - 4 weeks to sea water and then released in the lower reaches of the river gave a better return than fish that were released there without adaptation (Jensen, 1979). The author explains this by the fact that the adapted juvenile fish pass through the estuary zone more rapidly and move at a greater depth than do the unadapted fish, owing to which the effect of the predators is diminished. Possibly added to this also is the effect of the inhibition of desmoltification by the sea water.

Drawbacks: parr that get into sea water of high salinity are not able to adapt and they die. Our experiments have shown that even in brackish water the differences in the state of the hatchery-reared and the wild fish are initially intensified and only later become reduced (Bakstansky et al., 1980). The adult fish do not return into the river but to the region where the holding nets had been set up (Sutterlin et al., 1982; Reinert, 1982).

Release into the sea with delay. The juvenile fish are kept in holding nets in the sea for a prolonged period and are released after the completion of the migration period of the smolts. The results of many experiments show that a delayed release gives a higher return than the release into the sea with adaptation. In 1980 - 1982 in the northern part of the Gulf of Bothnia Swedish scientists (Eriksson, 1988) released smolts of the Baltic salmon. In the period, corresponding to the time of the migration of the wild smolts, hatchery-reared smolts were transported into holding nets in the sea, from which they were released in June, August, September and December. Control batches were released in the river. In all three

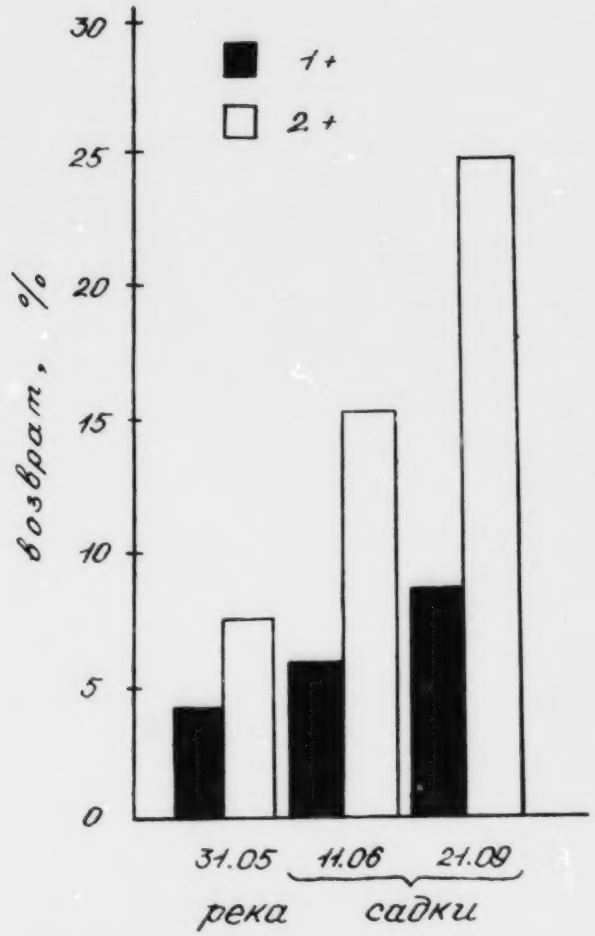

Рис.21. Возврат от смолтов разного возраста, выпущенных в реку и в море (из Eriksson,1988, с изменениями).

Figure 21. Return from smolts of different age, released in the river and in the sea (from Eriksson, 1988, with modifications).

Along the vertical: *возврат* [*vozvrat*], % - return, %
Along horizontal: *река* [*reka*] - river; *садки* [*sadki*] - holding nets

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years the return from the juvenile fish released in the river was smaller than the return from the fish released in the sea, and among the latter the later the fish were released the greater was the return (Figure 21). In Canada the return from juvenile fish released from a holding net 3 days after planting comprised 0.84%, while the return from fish that spent 21 days in the holding net was 1.37% (Sutterlin et al., 1982). In Norway the fish were held in holding

Table 47

Return of juvenile fish released after different periods of stay in sea water (according to the data of K. Jenssen, 1979)

Holding period in sea water, days	Length, cm	Return, %
0 - 2	12 - 36	0.3 - 3.7
180	18 - 29	14.9
540	21 - 48	10.8

Table 48

Return of smolts of the Atlantic salmon, released at an age of 2+ in the estuary of the Imsa river

Parental stock	Delay period, weeks	Date of release	Length, cm	Interval, cm	Return, %
Imsa	Control	19 May	24.7	14 - 32	5.3
	0	19 May	25.2	14 - 35	5.1
	4	22 June	25.5	14 - 39	4.3
	7	9 July	28.3	15 - 34	5.4
Sandvik	Control	19 May	22.5	13 - 32	9.8
	0	19 May	19.7	13 - 33	8.9
	4	22 June	23.4	13 - 34	6.3
Figga	Control	19 May	17.6	13 - 41	1.7
	0	19 May	17.7	14 - 34	1.2
	4	22 June	21.2	13 - 34	0.4
	7	2 July	35.0	28 - 41	6.4

NOTE. The smolts were held for 4 weeks in brackish water (10‰) in the period of smoltification, and prior to their release they were kept for a period of 0 - 7 weeks in sea water (32‰). The control groups of smolts were held only in freshwater (Hansen and Jonsson, 1986).

nets for up to 1.5 years (Table 47). It was found that the largest fish did not go out to sea after their release from the holding net, but remained near the holding nets or migrated into freshwater (Jenssen, 1979). Disruption of the migration behaviour in fish that were released with a delay was also noted for the Baltic salmon (Eriksson, 1988). In the first place, in step with the prolongation of the delay period there occurs an increase in the number of post-smolts caught in the region of the holding net over the course of the 2 - 3 weeks after the

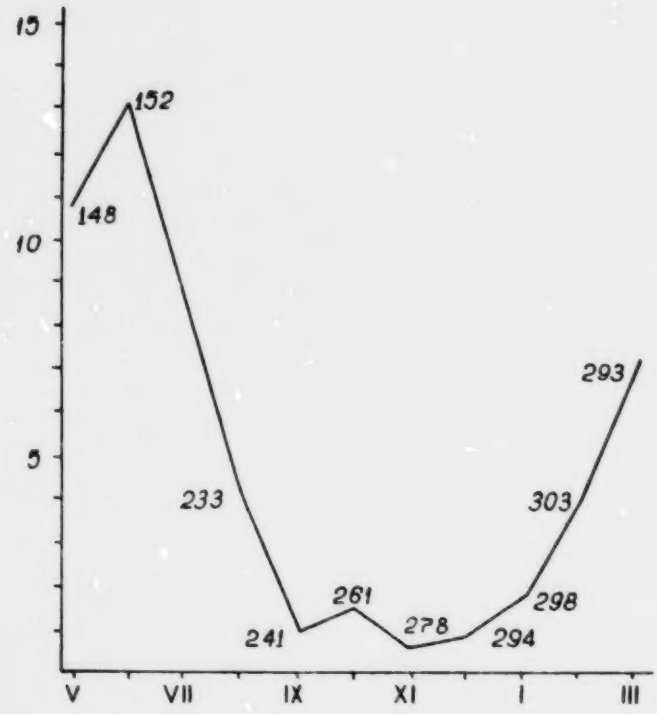

Рис.22. Возврат от молоди, выпущенной после задержки в морской воде (из Hansen, Jonsson, 1989, с изменениями). По вертикали: возврат, %, по горизонтали: время выпуска, мес. Цифрами обозначена средняя длина выпускаемой молоди, мм.

Figure 22. Return from juvenile fish released after holding in sea water (from Hansen and Jonsson, 1989, with modifications). Along the vertical: return, %; along the horizontal: times of release, months. The numbers denote the average length of the released juvenile fish, mm.

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release. From a batch of two thousand fish with a June release not even one was caught; with an August release - one was caught, and with a September release - 273 were caught close to the holding net. Secondly, in the fish released with a great delay the distance of the feeding migration is reduced, in some cases by half. However, contrary results have also been obtained from this same Norway (Table 48): fish that were held in sea water for 4 weeks gave the mininal return in all three groups. The authors explained this by the argument that these fish had migrated into the sea in non-optimal conditions. However, a delay for another 3 weeks gave the maximal return, which, in the opinion of the authors, may be explained by the marked growth of the fish.

In a later study these same authors showed that, with the delay of juvenile fish in sea water, the maximal return was given by those juvenile fish which were released in the period of the migration of the wild smolts. The growth of the detained young salmon influenced the return to a lesser extent than did the period of the release (Figure 22). Thus, the results of the delayed release are quite contradictory. At the present time it is difficult to unequivocally determine what factor increases the return: the time of the release or the increase in the size of the fish during the time of the delay.

Each of the listed release variants have their advantages and drawbacks. The selection of one or other of the release methods should not be done on the basis of an abstract comparison of the advantages and drawbacks, but rather on the basis of the specific characteristics of the juvenile fish, of their quality and quantity, of the necessity for the transportation of the fish and of the conditions awaiting the young salmon in the river. While it is advisable to standardize the biotechnology of hatchery rearing to the maximal degree, so as to make use of standard equipment, the biotechnology of the release should be "piecemeal". The technology of the release should be created specially for each hatchery - river combination. For the Kandalaksha hatchery there are two variants of these at the present time: hatchery - Niva and hatchery - Luven'ga.

5. 4. Biotechnique of release, recommended for the Kandalaksha hatchery

With today's state of the Kandalaksha hatchery the following biotechniques for the preparation of juvenile fish for the transition into natural conditions and for their release seem to be realistic.

Training and selection. The rearing of the salmon with the use of the "*Turnir*" apparatus will promote their physical development. Towards the end of the second year of rearing it is necessary to sort the fish. The purpose of this should not be to select the potential smolts (which is difficult to accomplish at the present time) but rather to screen out the hatch-

ery parr. This may be achieved by sorting out the small fish. Sorting of the juvenile fish into two or three groups is repeatedly carried out in hatcheries, but the final sorting should be differentiated from the preceding ones by the fact that the juvenile fish are not divided into small, medium and large, but rather into fish that have attained the threshold size and into fish that are smaller than the required size. The process itself of sorting by size has been well worked out and is carried out with the aid of a sorting lattice, the clearance between the rods of which is set up in such a way as to pick out the fish of the required size. For the juvenile salmon reared by the Kandalaksha hatchery the relationships between the thickness (T), mm, length (L), mm, and weight (W), g, were found to be as follows (Loenko et al., 1982):

$$L = 17.6\ T^{0.75}\ ,$$

$$W = 5.5\ T^{2.33} \cdot 10^{-3}\ .$$

Most debatable is the determination of the threshold sizes. We propose to consider as threshold the size attained by the wild juvenile fish at the end of the season of growth, preceding the migration into the sea. According to the data from back calculations (see Chapter 4. 3), this value comprises 12 cm. With such a length the juvenile fish of the Kandalaksha hatchery will have a body thickness of 13 mm and, consequently, such a clearance must be set up between the rods of the sorting lattice.

The small fish must be reared to an age of 3+. The release of fourth-year juvenile fish allows us not only to improve the survival of the hatchery-reared juvenile fish in the natural conditions, but also to increase the proportion of fish with a river age of 3+ in the return, which brings the age structure of the adult spawners of hatchery origin closer to the structure of the wild Luven'ga salmon, in which the river age of 3+ is modal (see Table 19).

Release into the Luven'ga. The Luven'ga is a clean river with a large number of growth areas and with a surviving natural population of salmon (see Chapter 2. 1). Consequently, the release should be organized in such a way as to ensure a good survival of the hatchery-reared juvenile fish and so as to cause no injury to the wild fish. The release in the Luven'ga requires the transportation of the juvenile fish. The released young salmon find

themselves in water other than that in which they had grown. For this reason, the fish released into the Luven'ga require opportunities for relieving the stress caused by the transportation and for adaptation to the new environmental conditions. This may be achieved with the release of the downstream migrants by way of adaptation holding nets. It is convenient to set these up 14 km upstream from the estuary, where there is a landing area that is suitable for putting down the helicopter. A live-fish truck can also drive up to this place, after some small repairs to the road. On the first trip are carried up the structural elements for the channel holding nets, while on the following trips are brought up the juvenile fish. The transportation may be started after the water in the Luven'ga has warmed up to +5°. The juvenile fish will remain in the holding nets up until the beginning of the migration of the wild smolts. The fish in the holding nets are fed with granulated feed, as much as they would consume. With the onset of the migration of the wild smolts, the hatchery-reared fish are released from the holding net in small batches. With this release variant the hatchery-reared pre-smolts complete smoltification in the conditions of the natural hydrological regime, due to which there appears in them the instinct to return into the Luven'ga and not into the Niva. Feeding with natural food improves the physiological state of the juvenile fish. The large hatchery-reared parr, which find themselves in a batch of released juveniles, can find a refuge for themselves, after leaving the holding net, along the 14 km section of the river from the release site to the estuary.

As was shown in Chapters 3 and 4, such an organization of the release has had a positive effect on the quality of the juvenile fish and on their survival after release. The small schools of hatchery-reared of silvery smolts and parr are found to be in no state to drive the wild parr out of their territories.

Release into the Niva. The Niva is a polluted river, with an unstable hydrological regime, due to the operation of the hydroelectric power plant. There are few places suitable for the habitation of released juvenile fish. Release into the Niva, however, does not require transportation of the fish, and smoltification may be completed in Niva water directly in the

conditions of the fish hatchery. For this reason the release should be organized in such a fashion that the hatchery-reared juvenile fish do not remain for long in the Niva.

The direct method was recommended by us for the release of the production of the Kandalaksha fish hatchery into the Niva (Chernitskii et al., 1989). The release was organized in the following manner: a year before the release, in the spring, the large juvenile fish were planted into a pond, where they also overwintered. The pond is equipped with an outlet gutter, installed at the normal retention level. For the release of the fish the water level was raised by 30 cm with the outlet closed, and then the outlet was opened. The juvenile fish that were ready for the transition into the sea could leave together with the upper layer of water that was pouring out. The discharge of the water lasted for about 5 hours. This procedure was repeated daily from June 20 until July 1. The released fish got into the old river bed of the Niva, above the retaining dam. The dam forms a small reservoir, from which the hatchery pumps in its water. The reservoir has a weak flow. The water flows across the dam and then, as a narrow stream 1 km in length, it flows into the sea.

With such a release variant the juvenile fish can move out of the pond in step with their physiological preparedness and rapidly leave the Niva. As has been shown by the first catches of the salmon that were returning into the Niva, the return consisted namely of those fish which departed into the sea in the year of their release, while in the return of the hatchery reared fish in the Luven'ga there predominated fish that remained in the river for a year after their release (Table 49).

Table 49

Age make-up of hatchery-reared spawners returning into the Luven'ga and Niva rivers after release from the Kandalaksha fish hatchery, %

River	Number of fish	Proportion of fish with a river age of			
		2+	3+	4+	5+
Luven'ga	484	33.0	55.8	11.0	0.2
Niva	373	94.9	5.1	0	0

The direct release of the juvenile fish into the Niva produced the first officially recorded return of hatchery-reared salmon following the construction of the hatchery (Chernitskii, 1989). Only now, 30 years after the Kandalaksha fish hatchery was put into operation, can one speak of carrying out the task for the sake of which it was constructed, the production and replacement of salmon in the Niva river. Up until the present time, however, there have been no generally acknowledged principles for evaluating the effectiveness of the work of the fish hatchery.

Chapter 6. EFFECTIVENESS OF THE WORK OF THE KANDALAKSHA FISH HATCHERY

It is not possible to improve the biotechnology for the hatchery rearing of salmon without adequate criteria for evaluating the results of the hatchery operations. Up until now there have been no such criteria. At the present time the effectiveness of the work of salmon hatcheries is evaluated on the basis of several quantities.

The number of juvenile fish released - the basic design index for salmon hatcheries - reflects the results of the work of the hatchery on the rearing of the juvenile fish, but not its ultimate objective, which is the augmentation of of the numbers of adult fish. Many examples are known of how fish hatcheries, while fulfilling their plan as to the numbers of juvenile fish released, have no effect at all on the salmon stocks in the region of their activity (Bakshtanskii et al., 1980). The data obtained show that a change in the numbers of juvenile fish released is not reflected in the absolute numbers of returning salmon. The relative size of the return even decreases with an increase in the volume of the release (Figure 7) and,

consequently, the numbers of juvenile fish released should be determined on the basis of the acceptance capacity of the particular body of water.

The proportion of hatchery-reared fish in the population. An evaluation of the results of a hatchery's activity based on the proportion of hatchery-reared fish among the spawners in a given river is not informative, since an increase in the proportion of hatchery-reared fish may be explained not only by the good work of the hatchery but also by a reduction in the natural reproduction. An improvement in the natural reproduction, moreover, is expressed in a reduction of the proportion of the hatchery-reared fish. Nevertheless, data about an increase in the proportion of hatchery-reared fish in the catches have been cited as evidence of a high effectiveness of fish-breeding operations (Kazakov, 1981, 1982), without taking into account the overall state of the stocks. It is obviously advisable to make use of this index for evaluating causes of fluctuations in the numbers of populations that are maintained by both hatchery-reared and natural reproduction, but not as an index of the effectiveness of the fish-breeding operations.

The quantity of the fishery return. This index is often utilized without defining the sense imparted to it. For example, I. B. Bukhanevich and L. A. Erman (1983) proposed an algorithm for determining the coefficient of the fishery return of sturgeons, which can be implemented on an electronic computer, but at the same time they did not define the term "fishery return". This term was also similarly used, without definition, in a review by G. A. Bogdanov and and E. E. Shevtsova (1978). Apparently, many assume that its content is generally accepted. However, even from an analysis of the literature of recent years, it is evident that different authors treat this in different ways.

Thus, R. V. Kazakov (1982, p. 12) considers that this quantity "shows what number of adult individuals out of the number reared by the hatchery is returned into the fishery (sea and river)". Such a treatment allows one to interpret the term return as the absolute number of spawners, and as the percentage survival of the released juvenile fish, and as the proportion of the hatchery-reared fish in the population.

A stricter definition is given in the book by V. K. Kiselev and R. V. Kiseleva (1983, p. 27): "The fishery return is the increase in the catch as a result of the accomplishment of some measures relating to the reproduction of the fish stocks. The absolute quantity of the fishery return is measured in units of specimens and units of mass (weight). The relative quantity of the fishery return is measured in the proportion of the fish making up the increase in the catch, expressed in percentages of the number of juvenile fish (eggs, sac fry) providing for this increase". From this definition it is evident that both the absolute and the relative quantities of the fishery return may be changed without changing the effectiveness of the work of the hatcheries. Thus, with a decrease or an increase in the numbers of the reared juvenile fish, there may occur corresponding changes in the absolute quantity, with an unchanged value of the relative quantity. The relative quantity will change with a constant absolute quantity, if we will compare one and the same number of returning spawners with the hatchery-reared juvenile fish at different stages of development (eggs, sac fry, yearlings, released juvenile fish, and juvenile fish migrating in the year of the release or after overwintering). For example, 267 spawners returned from the 1979 - 1985 releases. If one relates this number of spawners to all of the released juvenile fish (212.4 thousand fish), then the return comprises 0.10%, but if one consider the return only of those juvenile fish that migrated into the sea (35 thousand) , then it increases to 0.76%. Out of the 267 spawners, 213 were the return from juvenile fish that overwintered in the river. Comparing this number with the number of young salmon that remained to overwinter (184.7 thousand), we will obtain a return of 0.12%. However, if we divide 213 into 7.2 thousand, namely the number of overwintered fish that departed into the sea, then the return will increase to 2.95%, i.e. a 25-fold increase in the quantity of the fishery return is achieved simply by changing an initial figure for the calculation. (Table 11 illustrates this in greater detail).

However, even in the case when the relative return is calculated on the number of juvenile fish released, it nevertheless can not provide evidence as to the effectiveness of the work of a hatchery, since it is a relative index. Indeed, is the work effective at a return of 0.5%, or 1% or 5%? By itself, the quantity of the return does not provide an answer to this

question. It may be used only for a "larger - smaller" or "better - worse" comparative evaluation. Thus, a comparison of the values of the return of wild and hatchery-reared juvenile fish, obtained as a result of a wide-scale international program of tagging of juvenile fish, has shown that hatchery-reared juvenile fish have a much poorer survival in the sea than wild fish in all countries that rear the Atlantic salmon (Table 50). For this reason it is advisable to make use of this criterion namely for comparing different variants or rearing, release, etc.

Table 50

Return of hatchery-reared and wild downstream migrants on the basis of tagging data (Bakshtanskii et al., 1981)

Region of study	Return, %		Years of tagging
	hatchery-reared	wild	
England	0.06	1.45	1960 - 1971
England	0.03	1.24	1963 - 1971
Scotland	0.54	2.34	1960 - 1971
Scotland	0.2 - 1.7	1.5 - 5.7	1966 - 1969
Scotland	0.38	2.37	1963 - 1971
Ireland	0.12	1.39	1960 - 1971
Iceland	0.0	2.17	1960 - 1971
Canada	0.0 - 2.3	0.1 - 3.3	1968
Canada	0.55	2.07	1963 - 1971
Norway	2.16	4.28	1960 - 1971
USSR, Baltic	4.0	8.0	1960 - 1970
USSR, Atlantic	0.0	0.0 - 2.0	1969 - 1974
Finland	1.7 - 18.0	3.9 - 23.7	1972 - 1975
France	0.0	0.72	1960 - 1971
Sweden, Baltic	5.9 - 13.2	19.5 - 25.6	1961 - 1964
Sweden, Atlantic	7.0	9.6	1966 - 1971

We will nevertheless attempt to calculate what coefficient of return will provide evidence about the effectiveness of the Kandalaksha fish hatchery. For this purpose we will estimate the ratio of the overall weight of the released juvenile fish and the weight of the adult salmon that returned from the former. For the initial quantities we will turn to Tables 22 and

23, containing the data on the numbers of returning hatchery-reared fish of different age. Since, as was shown in Chapter 2. 4, the adult spawners were analyzed at various times after they had put in to the river, i.e. with different weight losses, average values (obtained from fish measured at the moment of their entry into the Luven'ga) were used for the weight characteristics of each age group (Table 51). The number of salmon in the return of each generation, the age composition and the average weight of the fish of each age allow us to calculate the overall weight of the return. This quantity may be compared both with the weight of all of the juvenile fish released and also with the weight of the juvenile fish that departed into the sea.

Table 51

Average measured weight of the Luven'ga river salmon of different age

River age	Sea age		
	1 +	2 +	3 +
2 +	1.5	4.2	6.9
3 +	1.5	4.6	11.8
4 +	1.7	4.4	9.1
5 +	2.0	-	-

With both of the calculation variants the final sum obtained is not comforting (Table 52). The weight of the return is not only lower than the weight of the released juvenile fish but is even lower than the weight of that portion which migrated out to sea. The weight of the return comprised 12% of the weight of the release and 60% of the weight of the migrants. Over the 8 years that were analyzed about 5 tons of juvenile fish were released, of which about 1 ton departed into the sea, and there returned into the Luven'ga about 6 centners. During this period 4 tons were lost in the river and 374 kg in the sea, although in 1982 and 1984 the weight of the return exceeded the weight of the migrants by 15 and 44 kg. If one excludes from the calculation the years 1979 and 1980, which were not typical as to the numbers of juvenile fish released, the result remains almost the same.

Table 52

Weight relationships of the released, migrating and returning salmon, kg

Yearof release	Release	Migrants 2+	Smolts 3+	Smolts 4+	Migrants 2+, 3+, 4+	Return	Return, as % of weight of release	Return, as % of weight of migrants 2+ 4+
1979	1056	168	37	1	206	27	3	13
1980	149	94	12	1	107	49	33	46
1981	722	85	7	11	103	62	9	60
1982	714	41	24	2	67	82	12	122
1983	477	136	8	7	151	74	16	49
1984	356	41	13	5	59	103	29	175
1985	702	127	24	9	160	102	15	64
1986	666	65	21	2	88	68	10	77
Total	4842	757	146	38	941	567	12	60
1981 - 1986	3637	495	97	36	628	491	14	78

What should be the return, so that it should at least compensate for the weight of the downstream migrants? On the basis of the data in Table 9 we will assume the weight of a downstream migrant as equal to 20 g. The average weight of an adult salmon, on the basis of Table 51, we will assume as 2 kg. One such salmon will be equal in weight to 100 downstream migrants, i.e. if out of 100 downstream migrants, each weighing 20 g, there returns one fish weighing 2 kg, then the mass of the release and of the return will be the same. Consequently, with such initial data , the compensation by weight of the release will be attained at a return that is equal to 1%. It is easy to show, however, that, with this method for evaluating the effectiveness, the compensation may be attained by decreasing the weight of the downstream migrant.

Let us assume as a condition of the effectiveness a compensation of the expenses for rearing the juvenile fish and the value of the return. We will take the initial data in Tables 9 and 51. The cost price of one hatchery-reared downstream migrant we will accept as being equal to 70 kopecks, although in some individual years a downstream migrant cost even more than a ruble. Having determined the cost of the whole release for each year (for which we multiply the number of downstream migrants released by 0.7 rubles), we then divide the

Table 53

Cost of 1 kg of hatchery-reared salmon at different stages of the ontogeny

Year of release	Downstream migrant [released]				Migrant [into sea]		Return	
	thousand fish released	cost of entire release, thous. rub.	weight of release, kg	cost of 1 kg, rubles	weight, kg	cost of 1 kg, rubles	weight, kg	cost of 1 kg, rubles
1979	59	41.3	1056	39	206	200	27	1530
1980	5	3.5	149	23	107	33	49	71
1981	37	25.9	722	36	103	251	62	418
1982	39	27.3	714	38	67	407	82	333
1983	22	15.4	477	32	151	102	74	208
1984	20	14.0	356	39	59	2378	103	134
1985	29	20.3	702	29	160	127	102	199
1986	30	21.0	666	32	88	239	68	309
Total	241	168.7	4342	35	941	179	567	298
1981 - 1986	177	123.9	3637	34	628	197	491	252

quantity obtained, in turn, by the weight of all the downstream migrants released, by the weight of those migrating out to sea and by the weight of the return (Table 53). The figures obtained are astounding: a kilogram of the downstream migrant costs no less than a kilogram of adult salmon on the black market, where the prices range from 15 to 30 rubles. A kilogram of the juvenile fish that are migrating into the sea already costs 5 times as much, and each such fish, at a weight of 25 g (see Table 25), will cost 4.5 rubles. A kilogram of the adult fish goes up even more in cost by a factor of 1.7 times. At an average weight of the Luven'ga salmon of 2 kg, such a fish will cost 600 rubles. If one excludes from the calculation the years 1979 and 1980, when atypical numbers of juvenile fish were released, the results do not differ in principle.

The cost of the hatchery-reared salmon, calculated on the basis of the cost of production of the released downstream migrants, considerably exceed any reasonable value. On account of the mortality of the released juvenile fish in the river, the cost of the return increases 5 times. The mortality of the fish in the sea increases the cost another 1.7 times.

Consequently, the effect of the river period of the life of the hatchery-reared juvenile fish on the price is found to be 3 times greater than that of the marine period.

What then should be the return that would compensate for the cost of the released downstream migrants? One hundred downstream migrants at 70 kopecks cost 70 rubles. With a receiving price of 5.5 rubles for 1 kg of salmon and a 2 kg weight of the fish it would cost 11 rubles, i.e. 6 such fish would cost as much as 100 released downstream migrants, and this means that at such prices the expenses would be compensated for at a return of 6%. This, however, is an unrealistic quantity. In the designs for salmon hatcheries a return of 5% of the released juvenile fish is postulated. With the preservation of the other conditions assumed in the previous calculation, from 100 young salmon we obtain 5 fish with a total weight of 10 kg. A kilogram of such salmon would cost 7 rubles. However, even a return of 5% of the fish is unattainable, at least at the present time. For the wild juvenile fish on the Luven'ga river the return, based on many years of data, comprised 3% (Table 13). With such a return of hatchery-reared downstream migrants, out of one hundred there would return 3 fish, with an overall weight of 6 kg. One kilogram of such salmon would cost about 12 rubles. From this it follows that, in order to achieve an economic effectiveness of the fish breeding, it is necessary not only to increase the survival rate of the fish after the release but also to decrease the cost of production of the downstream migrants.

And here is manifested one other fundamental defect of the quantity of the fishery return as an index of the effectiveness of the work of a fish hatchery: not reflected in such an index are the losses of spawners, eggs, and juvenile fish at stages preceding that stage on the basis of which the calculation is made. In the early stages of salmon rearing, when the hatcheries released sac fry and fingerlings, the fishery return, defined as the ratio of the release to the catch (Tikhii, 1924; Cherfas, 1940), characterized the effectiveness of the work of the hatcheries in adequate measure, since the major mortality of the juvenile fish occurred after the release from the hatcheries. At the present time, when the juvenile salmon are kept under the control of fish culturists for 2 - 4 years, the relative return may easily be increased by means of the selection of a batch, of restricted size, of the most viable juvenile fish. The

transfer of data on the return from individual batches of selected juvenile fish onto all of the production released by some hatchery or other may disorient some fishery departments. We may note that various indices, supplementing the coefficient of fishery return, have been proposed by various investigators, both in our country as well as abroad (see Kozhin, 1951; Tave, 1984).

It is obvious that the criteria, on the basis of which one may evaluate the effectiveness of the work of a hatchery, should reflect the fundamental aim for which the hatchery was created. If this aim was considered to be the rearing of juvenile fish, then the quantity and quality of the juvenile fish released will adequately reflect the successes and achievements of this aim. If, on the other hand, one considers that the fundamental task of salmon hatcheries is to increase the supply or quantity of fish available to the fishery, then the absolute value of the fishery return will be an indicator of the fulfillment of this task.

One should not forget, however, that an aim of the construction of fish hatcheries is the reproduction of salmon. All of the existing hatcheries have been constructed either to compensate for a loss inflicted by hydraulic engineering constructions to the reproduction of the fish stocks, or as a result of the representations made by various authors about the greater effectiveness of hatchery reproduction as compared with natural reproduction (see, for example, Kazakov, 1982, p. 17). For this reason an index is needed that reflects namely the contribution of the hatchery in the reproduction. In our opinion, the coefficient of reproduction (the ratio of the spawners utilized for obtaining the fish of a given generation and spawners obtained from that generation) may serve as such an index. The quantity of the two groups of fish may be expressed in numbers of individuals or in kilograms. Such an index allows us to evaluate namely the quality of the reproduction of the salmon and to reflect, in an integral fashion, the effectiveness of all of the stages of the fishery, from the survival of of the spawners in the hatchery holding tanks to the survival of the juvenile fish in the sea.

In Table 54 are presented calculations of coefficients of reproduction for salmon released in the Luven'ga by the Kandalaksha hatchery. While the numbers of spawners, used for obtaining the juvenile fish released into the Luven'ga, were known for the 1979-1983

Table 54

Calculation of the coefficient of reproduction for the hatchery-reared salmon released in the Luven'ga river

Generation	Spawners used, indivs.			Juveniles released, thousands	Spawners returned, individuals	Coefficient of reproduction	Return from the released juvenile fish, %
	♂	♀	Total				
1975	26	24	50	41.3	17	0.34	0.04
1976	18	17	35	58.6	9	0.26	0.02
1977	6	5	11	5.1	22	2.00	0.43
1978	12	11	23	36.5	37	1.61	0.10
1979	39	35	74	39.4	44	0.59	0.11
1980	43	40	83	24	44	0.53	0.18
1981	37	34	71	19.8	59	0.83	0.30
1982	46	42	88	29.0	52	0.59	0.18
1983	55	50	105	31.4	53	0.50	0.17
Total 1975 - 1983			540	285.1	337	0.62	0.12
1979 - 1983			421	143.6	252	0.60	0.18

NOTE. In 1975 - 1978 spawners from the Kola river were used, - the average working fecundity of a female was 9.8 thousand eggs; in 1979 - 1983 - spawners from the Luven'ga river, with an average working fecundity of 4.9 thousand eggs. The 1976 generation (juvenile fish from the Taibol'skii hatchery) were raised for a year in the Kandalaksha hatchery, from an age of 1+ to an age of 2+. The 1977 generation comprised juvenile fish from the Knyazhegubskii hatchery.

generations, for the preceding generations it was necessary to calculate the numbers of spawners, whose progeny was released into the Luven'ga, in a special fashion. For this it was determined what proportion of the juvenile fish of a given generation was released namely into the Luven'ga, and it was considered that a corresponding proportion of the spawners used for obtaining all of the juvenile fish was apportioned for the juvenile fish released into the Luven'ga. Over the 9 years there were released into the Luven'ga the progeny of 540 fish, which produced a return of 337 fish. The coefficient of reproduction comprised 0.62, i.e. as a result of the activity of the hatchery 6 fish were obtained from 10 fish. In other words, the hatchery removed more fish from the population than it produced. Only two generations gave a coefficient of reproduction that was greater than unity. These were the 1977 and 1978 generations. Both of the latter were obtained from large fish from

Table 55

Calculation of the coefficient of reproduction for the wild salmon of the Luven'ga river

Generation	Spawners let through to spawn, individuals.			Migrating juveniles, individuals	Spawners returned, individuals	Coefficient of reproduction	Return from the smolts %
	♂	♀	Total				
1979	41	17	58	3184	134	2.31	4.21
1980	11	18	29	2813	168	5.79	5.97
1981	9	5	14	9107	198	14.14	2.17
1982	22	22	44	15953	206	4.68	1.29
1983 *	22	21	43	2311	127	2.95	5.50
Total			188	33368	833	4.43	2.50

* Calculation made only on the basis of fish with a river age of 2+ and 3+.

the Kola river. From 1979 Luven'ga spawners were utilized for rearing the juvenile fish that were released into the Luven'ga. Since the fecundity of these fish was half of that of the Kola fish, the numbers of females and males utilized also increased.

Over the 5 years of using the Luven'ga spawners, a return of 252 fish was obtained from 421 salmon. The coefficient of reproduction comprised 0.60. In these same years 188 salmon were let through into the river for spawning, from which number there returned 833 fishj (Table 55). The coefficient of reproduction comprised 4.43. The minimal value of this index did not drop below 2.31. In comparing the values of the coefficients of reproduction, 0.60 and 4.43, we find that the natural reproduction of the salmon in the Luven'ga is 7 times more effective than the hatchery reproduction. From Tables 54 and 55 it can be seen that the changes in the values of the coefficients of reproduction are not associated with changes in the percentage of the return from the downstream migrants or smolts. There is displayed a tendency towards a negative correlation of the coefficient of reproduction with the numbers of spawners used (let through for spawning) (-0.7 and -0.9). For this reason the use of the coefficient of reproduction allows one to compare the effectiveness of the hatchery and natural reproduction of the fish in different regions. With its aid it may be possible to determine the optimal capacity of hatcheries.

The proposed index requires that the numbers of returning spawners be taken into account, which is complicated by the effect of foreign and illegal fishing, the differing intensity of the fishery in different regions, and other factors. However these same causes are important also with any methods for evaluating the activity of hatcheries, associated with an accounting of the fishery return.

For certain practical tasks there may be utilized a cruder but simple method for calculating the coefficient of reproduction, which does not require tracing the fate of every generation and an age analysis of the return. By summing up the number of spawners, used for obtaining the hatchery-reared juvenile fish over a particular period of time, and by dividing up this amount by the number of hatchery-reared fish returning during this same period, we will obtain an amount which may be considered as an approximate estimate of the coefficient of reproduction. Such estimates, which have been calculated by us on the basis of record data of the *Murmanrybvod* [Murmansk Directorate of Pisciculture] for four hatcheries, are presented in Table 56. As can be seen from this Table, the value of the coefficient of reproduction obtained by this method for the Kandalaksha hatchery is in good agreement with the value obtained by the precise method (Table 54).

Table 56

Approximate values of the coefficients of reproduction of salmon for fish hatcheries of the *Murmanrybvod* [Murmansk Directorate of Pisciculture]

Hatchery	Body of water where release made	Period of observations	Number of spawners utilized	Number of spawners returned	Coefficient of reproduction
Kandalaksha	Luven'ga river	1984 - 1988	488	304	0.6
Taibol'skii	Kola river	1985 - 1989	630	7566	12.0
Umbskii	Umba river	1985 - 1989	816	359	0.4
Knyazhegubskii	White Sea Knyazhaya Bay	1985 - 1989	355	706	2.0

For the Kandalaksha and Umbskii hatcheries the coefficient of reproduction is less than one, while for the Knyazhegubskii and Taibol'skii hatcheries it is more than one. It may be assumed that the reason for the high effectiveness of the Taibol'skii hatchery is to be found in the good conditions in which the juvenile fish, released into the Kola river, find themselves (Smirnov et al., 1985). The release is made in seven sections of the river, in small batches. The absence of wild young salmon saves the hatchery-reared juvenile fish from competition. The example of the Taibol'skii hatchery shows that fish hatcheries in the North may operate effectively.

CONCLUSION

The rearing of juvenile fish in fish hatcheries is often considered as the only method for preserving populations of salmon that have lost the opportunity for natural reproduction. Poor results of fish breeding are explained by a low effectiveness of the existing hatcheries, by imperfection of the biotechnology and by an inferiority of the feeds. However the very possibility of the reproduction of salmon populations by hatchery rearing is usually not called into question.

At the present time juvenile fish develop in hatchery conditions up to the smolt stage (1 - 3 years). Economic considerations dictate the necessity for obtaining maximal production in minimal time and with minimal expenditure. For this purpose dense stocking of the juvenile fish, and regulated temperature and lighting regimes are employed, which creates ecological conditions in the fish hatcheries, that are drastically different from the natural conditions. It is known that in different ecological conditions the direction of selection is also different (Shvarts, 1980). The selection of the juvenile fish during the rearing in fish hatcheries is very intensive: the normative yield of silvery smolt comprises less than 30% of the number of fertilized eggs (Yandovskaya et al., 1979; see also Table 4). Thus, even with the use of spawners that represent all the diversity of the gene pool of the population that is being reproduced, the selection of the juvenile fish for adaptation to the hatchery conditions leads to the appearance of differences between the hatchery-reared and the wild juvenile fish. Genetic deviations have been revealed in the young salmon of the Kandalaksha hatchery, when compared with the juvenile fish from the Luven'ga river (Nikanorov et al., 1989). Comparative analysis has shown the presence of differences also in several other features. For this reason the hatchery-reared juvenile fish that find themselves in natural conditions often die in large numbers. The fish that have survived in the hatchery and in the river differ considerably from the wild fish in their age structure (Table 18). Data have also been obtained for other populations, in which spawners of hatchery origin play an appre-

ciable role, concerning changes in morphological and age characteristics (Zelinskii, 1979; Salmov, 1981; Stahl, 1983). Taking into consideration the great morphological plasticity of salmon, one may expect that, with the prolonged and widespread rearing of juvenile fish in fish hatcheries, undesirable changes will occur in the marketable qualities of the fish.

Consequently, the rearing of juvenile fish of a given population in a fish hatchery can not ensure the reproduction of this population because of the differences in the conditions of existence in the river and in the hatchery. For the reproduction of a specific population it is necessary to maximally preserve all of the peculiarities that are inherent to it: its size and age composition, the duration of the individual periods of ontogeny, their affinity to a defined combination of environmental conditions, etc. These peculiarities ensure the state of adaptation of a given population to the conditions in a specific river, and they are maintained by stabilizing selection. In the first phases of fish breeding, when the hatcheries released sac fry and fingerlings, the fish entered into the natural conditions at an early stage, and the stabilizing effect of the natural selection maintained the adaptive features of the population. In such a case the release of juvenile fish into rivers could even preserve the population and increase its numbers. At the present time, with the protracted periods of rearing the juvenile fish, individuals with different geno- and phenotypes survive in the hatchery and the river conditions, even from spawners with similar genotypes. With prolonged hatchery rearing, the salmon are affected by the two principal factors that determine the distinctiveness of ecogenesis with domestication (Raushenbakh, 1985): the weakening of the pressure of natural selection and the change in the vectors of selection, with the replacement of the action of natural selection by artificial selection. And so, with the hatchery rearing of juvenile salmon one may accomplish the task of propagating the salmon, i.e. increasing the catches by means of a pasturage rearing of fish in numbers that are not limited by the spawning and growth possibilities of a river. In this case the hatchery period should be maximal - up until the completion of smoltification, and then the juvenile fish would not be dependent on the feed capacity of the river. The selection for the return, which is an integral index of the state of adaptation of the fish to the conditions of habitation both in the hatchery as well as in the

sea (Kirpichnikov, 1979), promotes an increase in the effectiveness of the propagation. The simplest method for such selection is the utilization of only hatchery-reared spawners for obtaining the progeny, even if their piscicultural characteristics are poorer than in the wild fish (Chernitskii, 1985v).

The hatchery-reared fish that survive after their release are the carriers of the optimal genotype, allowing for survival both in the fish hatchery as well as in nature (Leshcheva and Zhuikov, 1989). The selection of such fish as the spawners for fish breeding would make it possible, in the opinion of the authors, to create, in a short period of time, populations of salmon that are optimally adapted to the specific conditions of each fish hatchery. To this it may be added that such fish will be adapted also to the release conditions. Only after the creation of stable populations, maintained by hatchery propagation, is it possible to carry out a selection of the fish on the basis of marketable and piscicultural indices.

The low effectiveness of salmom rearing, that has been noted both in the USSR as well as abroad, is in some measure determined by the atiempt to accomplish two tasks simultaneously by the rearing of the juvenile fish: to preserve particular populations (reproduction) and to obtain additional catch (propagation). it is therefore necessary to separate the tasks of reproduction and propagation, and to resolve them in principle by different means, directing oneself, accordingly, towards a biological or an economic effectiveness. Only in the latter case is it justified to accelerate the development of the fish by regulating the environmental factors and stimulating components in the feed, by the culling of slow-growing individuals, by increasing the density of the plantings, and by using hatcheries of greater capacity and other measures for reducing the cost of the rearing.

BIBLIOGRAPHY

1. ***Antonova V. P.*** Conditions of the downstream migration and biological characteristics of the migrating juvenile salmon of the Kedva river (Pechora basin). - In: Biological problems of the North. Part 2. [*In Russian*]. Magadan, Published by the Institute of Biological Problems of the North, 1983, p. 142 -143.

2. ***Bakshtanskii E. L. and Nesterov V. D.*** Behaviour of hatchery-reared downstream migrants of the Atlantic salmon after the period of adaptation to the natural conditions. - In: Ecology and reproduction of diadromous salmonid fishes in the basins of the White and Barents Seas. [*In Russian*]. Murmansk, Publ. PINRO [*Polyarnyi nauchno-issledovatel'skii institut morskogo rybnogo khozyaistva i okeano-grafii im. N. M. Knipovicha* - The N. M. Knipovich Polar Scientific Research Institute of Marine Fisheries and Oceanography], 1985, p. 88 -100.

3. ***Bakshtanskii E. L. and Chernitskii A. G.*** Ecological ways for increasing the effectiveness of the propagation of the Atlantic salmon. - In: Biological foundations for the development of a salmon industry in bodies of water in the USSR. [*In Russian*]. Moscow, "*Nauka*" Publ., 1983, p. 156 -170.

4. ***Bakshtanskii E. L., Nesterov V. D. and Simukov Yu. A.*** The state of salmon rearing in the Murmansk and Arkhangel'sk oblasts. - In: Salmonid fishes [*In Russian*]. Leningrad, "*Nauka*" Publ., 1980, p. 192 -206.

5. ***Bakshtanskii E. L., Nesterov V. D. and Chernitskii A. G.*** Recommendations on the release of juvenile Atlantic salmon and sea trout. [*In Russian*] - Moscow, Publ. VNIRO[*Vsesoyuznyi nauchno-issledovatel'skii institut morskogo rybnogo khozyaistva i okeanografii* - All-Union Scientific Research Institute of Marine Fisheries and Oceanography], 1981, 29 pp.

6. ***Barannikova I. A.*** The functional foundations of fish migration. [*In Russian*]. Leningrad, "*Nauka*" Publ., 1975, 210 pp.

7. ***Berezovskii A. I.*** A contribution to the question of the effectiveness and of the ways for the reconstruction of the artificial propagation of diadromous fishes. - *Rybnoe Khozyaistvo*, 1933, No. 2, p. 5 -7.

8. ***Bogdanov G. A. and Shevtsova E. E.*** Effectiveness of the work of salmon hatcheries abroad. - Review information, series. Fishery utilization of inland bodies of water. [*In Russian*]. Moscow, Publ. TsNIITE MRKh [*Tsentralnyi nauchno-issledovatel'skii institut informatsii i tekhniko-ekonomicheskikh issledovanii Ministerstva rybnogo khozyaistva* - Central Scientific Research Institute of Information and Technical and Economic Studies of the Ministry of Fisheries], 1978, issue 4, 40 pp.

9. ***Bugaev V. F., Pervozvanskii V. Ya., Shustov Yu. A. and Shchurov I. L.*** The devouring of hatchery-reared juvenile salmon by pike in the Keret' river - *Rybnoe Khozyaistvo*, 1986, No. 1, p. 51-52.

10. ***Bugaev V. F., Shustov Yu. A. and Shchurov I. L.*** Peculiarities of the downstream migration of hatchery-reared juvenile fish in the Keret' river (basin of the White Sea). - *Voprosy ikhtiologii*, 1987, vol. 27, issue 6, p. 1035-1037.

11. ***Bukhanevich I. B. and Erman L. A.*** Methodological instructions for determining the coefficient of the fishery return of sturgeons in the Volga. [*In Russian*]. Moscow. Publ. VNIRO, 1983, 33 pp.

12. ***Vernidub M. F.*** The exterior of the juvenile salmon and its changes in the process of growth. - In: Biology of commercial fishes of the inland bodies of water in the northern part of the European territory of the USSR. [*In Russian*]. Murmansk, Publ. PINRO, 1977, p. 119-131.

13. ***Vernidub M. F. and Yandovskaya N. I.*** Instructions on the holding of spawners, the collection, the fertilization and the rearing of the sac fry of the salmon in the conditions in the north-west of the USSR. [*In Russian*]. Moscow, *Pishcheprомizdat* [*Gosudarstvennoe nauchno-tekhnicheskoe izdatel'stvo pishchevoi promyshlennosti* - State Scientific and Technical Publishing House of the Food Industry], 1955, 38 pp.

14. ***Galkin G. G.*** The survival rate and growth of artificially reared juveniles of the Baltic salmon during the river period of their life. - *Izvestiya GosNIORKha* [*Gosudarstvennyi nauchno-issledovatel'skii institut ozernogo i rechnogo rybnogo khozyaistva* - State Scientific Research Institute of Lake and River Fisheries], 1961, vol. 51, p. 15-27.

15. ***Gol'dman R. S. and Chipulis V. P.*** Technical diagnosis of digital devices. Moscow, [*In Russian*]. "*Energiya*" Publ., 1976, 224 pp.

16. ***Grimm O.*** Conversations about fish breeding. [*In Russian*]. St. Petersburg, V. Demakov's Printing House, 1883, 54 pp.

17. ***Gruzdev A. I., Sidorov V. S., Smirnov Yu. A. and Chechenkov A. V.*** The activity of the lactate dehydrogenase isoenzymes during the necrosis of the fins in juvenile salmon. - *Voprosy ikhtiologii*, 1983, vol. 23, issue 4, p. 661-666.

18. ***Dirin D. K.*** The migration and age of smolts. - In: Raising the productivity and the rational utilization of the biological resources of the White Sea. [*In Russian*]. Leningrad, Publ. *Zoologicheskii institut AN SSSR* [Institute of Zoology of the Academy of Sciences of the USSR], 1982, p. 105-108.

19. ***Evropeitseva N. V.*** The transition to the downstream migrant stage and the downstream migration of juvenile salmon. *Uchenye zapiski LGU* [*Leningradskii Gosudarstvennyi Universitet* - Leningrad State University], 1957, issue 44, No. 228, p. 117-154.

20. ***Ermolaev G. I.*** Studies on the downstream migration of juvenile salmon in the Shuya river. - In: Reports of proceedings of the 2nd Republic-wide Conference of Young Scientists on Fishery Studies of Inland Waters. [In Russian]. Petrozavodsk, Publ. *SevrybNIIproekt*, 1980, p. 36-38.

21. ***Ermolaev G. I.*** The catadromous migration of wild and hatchery-reared juveniles of the Atlantic salmon in Karelia. - *Voprosy ikhtiologii*, 1988, vol. 28, issue 3, p. 326 - 403.

22. ***Zadorina V. M.*** Hydrobiological characteristics of some rivers on the Kola peninsula. - In: The ecology and reproduction of diadromous salmonid fishes in the basins of the White and Barents Seas. [*In Russian*]. Murmansk, Publ. PINRO, 1985, p. 138 -148.

23. ***Zelinskii Yu. P.*** The fishery return of salmon of hatchery production. - *Rybnoe Khozyaistvo*, 1979, No. 11, p. 30 -31.

24. ***Kazakov R. V.*** Propagation of the Atlantic salmon. 11. Effectiveness of the work of fish hatcheries. - *Sbornik nauchnykh trudov GosNIORKha*, 1987, No. 163, p. 13 - 23.

25. ***Kazakov R. V.*** The biological foundations for the propagation of the Atlantic salmon. Moscow, *Legkaya i pishchevaya promyshlennost'*, 1982, 144 pp.

26. ***Kazakov R. V.*** Comparative morphological characteristics of the smolts of sea trout and salmon from the Pyalitsa river (White Sea). - *Sbornik nauchnykh trudov GosNIORKha*, 1987, No. 263, p. 68 -125.

27. ***Kazakov R. V. and Kozlov V. V.*** Quantitative evaluation of the degree of silvering of juvenile Atlantic salmon of natural and hatchery origin. - In: Systematics and morphology of salmonid fishes. [*In Russian*]. Leningrad, Publ. *Zoologicheskii institut AN SSSR* [Institute of Zoology of the Academy of Sciences of the USSR], 1985, p. 119 -129.

28. ***Kazakov R. V. and Minina E. V.*** Characteristics of the biomechanics of the skin of juvenile salmon of hatchery and natural origin during the period of smoltification. - *Sbornik nauchnykh trudov GosNIORKha*, 1984, No. 220, p. 3 -13.

29. ***Kazakov R. V. and Semenova O. V.*** Morphological characteristics of hatchery-reared and natural juvenile salmon. - In: The morphology and ecology of fishes. [*In Russian*]. Leningrad, Publ. *Zool. institut AN SSSR*, 1986, p. 75 -86.

30. ***Kirpichnikov V. S.*** Genetic Foundations of fish breeding. [*In Russian*]. Leningrad, "*Nauka*" Publ., 1979, 393 pp.

31. ***Kiselev V. K. and Kiseleva R. A.*** Economics of the reproduction of fish stocks. [*In Russian*]. Moscow, *Legkaya i pishchevaya promyshlennost'*, 1983, 192 pp.

32. ***Kozhin N. I.*** Coefficient of the fishery return. - *Trudy VNIRO*, 1951, vol. 19, p. 127 -132.

33. ***Kostylev Yu. V. and Ermolaev G. I.*** Methodological instructions on the release of juvenile Atlantic salmon, reared in fish hatcheries in Karelia. [*In Russian*]. Petrozavodsk, Publ. *SevrybNIIproekt*, 1983, 14 p.

34. ***Kostylev Yu. V., Baletov V. A. and Ermolaev G. I.*** Ecological foundations for increasing the effectiveness of reproduction of lake salmon in the Karelian ASSR. - In: Questions relating to the natural reproduction and the morpho-physiological characteristics of the ontogeny of lake salmon with artificial propagation. [*In Russian*]. Murmansk, Publ. *PINRO*, 1980, p. 3-28.

35. ***Kruglova A. N.*** The zooplankton of small salmon rivers of the Kola peninsula. - In: Questions concerning the salmon industry in the European North. [*In Russian*]. Petrozavodsk, Publ. of the Karelian Branch of the Academy of Sciences of the USSR, 1987, p. 61-64.

36. ***Kuz'min O. G.*** A contribution to the biology of the salmon in the small salmon rivers of the Eastern Murman region. - In: The ecology and reproduction of diadromous salmonid fishes in the basins of the White and Barents Seas. [*In Russian*]. Murmansk, Publ. *PINRO*, 1985, p. 25-41.

37. ***Kuz'min O. G. and Smirnov Yu. A.*** The conditions of habitation and growth of juvenile salmon in small rivers on the Kola peninsula. - *Voprosy ikhtiologii*, 1982, vol. 22, issue 5, p. 773-781.

38. ***Levina E. M., Loenko A. A. and Chernitskii A. G.*** Requirements for means of transportation for the release of juvenile Atlantic salmon. - In: The ecology, biological productivity and questions of mariculture in the seas of Northern Europe. [*In Russian*]. Apatity, Publ. of the Kola Scientific Centre of the Academy of Sciences of the USSR, 1990, p. 102-104.

39. ***Leshcheva T. S. and Zhuikov A. Yu.*** The training of fish. [*In Russian*]. Moscow, Publ. "Nauka", 1989, 109 pp.

40. ***Loenko A. A.*** Identification of hatchery-reared juvenile salmon on the basis of the structure of the scales. - In: Studies on the biology, morphology and physiology of hydrobionts. [*In Russian*]. Apatity, Publ. of the Kola Branch of the Academy of Sciences of the USSR, 1983, p. 43-44.

41. ***Loenko A. A.*** Salmon of the Luven'ga river from natural and hatchery reproduction. - *Rybnoe Khozyaistvo*, 1985, No. 1, p. 30-33.

42. ***Loenko A. A.*** A contribution to the question of the effectiveness of the work of the Kandalaksha fish hatchery. - In: The ecology and reproduction of diadromous salmonid fishes in the basins of the White and Barents Seas. [*In Russian*]. Murmansk, Publ. *PINRO*, 1985 b, p. 101-110.

43. ***Loenko A. A.*** Comparative analysis of the work of salmon hatcheries in the Murmansk region. - In: The current state and the prospects for development of the salmon industry in the European North. [*In Russian*]. Murmansk, Publ. *PINRO*, 1986, p. 68-76.

44. ***Loenko A. A. and Chernitskii A. G.*** Characteristics of the migration behaviour of juvenile salmon after release from the Kandalaksha fish hatchery into the Luven'ga

river. - *Redkol. Vest. LGU. Ser. Biologiya.*, [*Redaktsionnaya kollegiya, Vestnik Leningradskogo Gosudarstvennogo Universiteta, Seriya Biologii* - Editorial Board of Herald of Leningrad State University, Biology Series], 1980, 16 pp. Manuscript deposited in *VINITI* [*Vsesoyuznyi institut nauchnoi i tekhnicheskoi informatsii* - All-Union Institute of Scientific and Technical Information], 14. 08. 80, No. 3656-80. Dep.

45. ***Loenko A. A. and Chernitskii A. G.*** Factors affecting the transition into a migrant state of juvenile salmon released from fish hatcheries. - *Voprosy ikhtiologii*, 1984, vol. 24, issue 2, p. 307 -315.

46. ***Loenko A. A. and Chernitskii A. G.*** Comparative analysis of smolts of the salmon and the sea trout. 1. Sex, age and size of the smolts. - In: Problems in the biology and ecology of the Atlantic salmon. [*In Russian*]. Leningrad, Publ. "*Nauka*", 1985, p. 163 -173.

47. ***Loenko A. A. and Chernitskii A. G.*** Comparative analysis of the migrations of the smolts of the salmon and the sea trout. - *Voprosy ikhtiologii*, 1986, vol. 26, issue 5, p. 795 -801.

48. ***Loenko A. A., Khuzin R. Sh. and Chernitskii A. G.*** Relationship of the size parameters of juvenile salmon. - *Rybnoe Khozyaistvo*, 1982, No. 10, p. 35 -36.

49. ***Loenko A. A., Ponomarev Yu.R. and Mit'kov Yu. O.*.** Preliminary results on the effectiveness of the work of the Knyazhegubskii fish hatchery. - In: Problems in the study, rational utilization and conservation of natural resources of the White Sea. [*In Russian*]. Leningrad, Publ. *GKNT SSSR* [*Gosudarstvennyi komitet Soveta Ministrov SSSR po nauke i tekhnike* - State Committee of the Council of Ministers of the USSR for Science and Technology], 1987, book 2, p. 330 -332.

50. ***Malikova E. M., Kotova N. I. and Reznikova N. S.*** Rearing juveniles of the Baltic salmon in fish hatcheries. [*In Russian*]. Riga, Publ. "*Zinatne*", 1969, 36 pp.

51. ***Martynov V. G.*** Salmon in the Ural tributaries of the Pechora river. Ecology, morphology, reproduction. [*In Russian*]. Leningrad, "*Nauka*" Publ., 1983, 127 pp.

52. ***Mel'nikova M. N.*** Some distinctive characteristics of juvenile salmon of several rivers in the basin of the White Sea. - *Voprosy ikhtiologii*, 1970, vol. 10, issue 3, p. 442 - 451.

53. ***Mitans A. R.*** The conditions of smoltification, the dynamics of the downstream migration and the numbers of downstream migrants of the salmon in the Salatsa river. - In: Fishery investigations in the basin of the Baltic Sea. [*In Russian*]. Riga, Publ. "*Zinatne*", 1967, No. 2, p. 35 -52.

54. ***Mitans A. R.*** Some characteristics of the river and hatchery-reared downstream migrants of the Latvian salmon. - In: Fishery investigations in the basin of the Baltic Sea. [*In Russian*]. Riga, Publ. "*Zinatne*", 1968, No. 4, p. 160 -182.

55. ***Mitans A. R.*** The behaviour, feeding and growth of hatchery-reared juvenile salmon after they are released into the river. - In: Fishery investigations in the basin of the Baltic Sea. [*In Russian*]. Riga, Publ. "*Zinatne*", 1970, No. 7, p.102-123.

56. ***Nikanorov S. I., Ofitserov M. V., Vitvitskaya L. V. and Loenko A. A.*** Uncontrolled genetic selection. - *Rybnoe Khozyaistvo*, 1989, No. 1, p. 54-55.

57. ***Nusenbaum L. M.*** The state and the ways of rationalization of the hatchery production of salmon. - *Vestnik LGU* [*Leningradskii Gosudarstvennyi Universitet* - Leningrad State University], 1950, No. 8, p. 117-128.

58. ***Nusenbaum L. M.*** A study of downstream migrant juvenile salmon. - *Rybnoe Khozyaistvo*, 1953, No. 9, p. 21-25.

59. ***Petrenko L. A.*** Comparative characteristics of river and hatchery-reared juvenile salmon in the river. - *Voprosy ikhtiologii*, 1964, vol. 4, issue 2, p. 342 - 347.

60. ***Petrenko L. A.*** Effectiveness of the artificial reproduction of the Atlantic salmon. - Izvestiya GosNIORKha [*Gosudarstvennyi nauchno-issledovatel'skii institut ozernogo i rechnogo rybnogo khozyaistva* - State Scientific Research Institute of Lake and River Fisheries], 1976, No. 112, p. 3-20.

61. ***Petrenko L. A.*** Some ways for increasing the effectiveness of hatchery propagation of Atlantic salmon. - In: Salmonid fishes. [*In Russian*]. Leningrad, Publ. "*Nauka*", 1980, p. 211-214.

62. "*Postanovlenie soveshchaniya*" ["Resolution of Conference"]. - In: Transactions of the Conference on the Fishery, convened by the Ministry of Agriculture in 1913. [*In Russian*]. 1914, Part 1, St. Petersburg, Kirshbaum's Printing House, p. 21-63.

63. ***Protasov A. A.*** Biotechnology for the artificial propagation of salmonids up to the downstream migrant stage. [*In Russian*]. Moscow, Publ. VNIRO, 1958, 60 pp.

64. ***Raushenbakh Yu. O.*** Ecogenesis of domestic animals. [*In Russian*]. Moscow, Publ. "*Nauka*", 1985, 198 pp.

65. ***Ryzhkov L. P., Popova E. K., Polina A. V. et al.*** Instructions for the incubation of the eggs and the rearing of the juveniles of the freshwater salmon in optimal temperature conditions. [*In Russian*]. Petrozavosk, Publ. SevNIORKh [*Severnyi gosudarstvennyi nauchno-issledovatel'skii institut ozernogo i rechnogo rybnogo khozyaistva* - Northern State Scientific Research Institute of Lake and River Fisheries], 1973, 29 pp.

66. ***Salmanov A. V.*** Osteological characteristics of hatchery-reared and juvenile salmon from the Luven'ga river. - In: The morphology and ecology of fishes. [*In Russian*]. Leningrad, Publ. Institute of Zoology of the Academy of Sciences of the USSR, 1986, p. 87-98.

67. ***Salmanov A. V.*** Analysis of the variability of morphometric indices in hatchery-reared and natural juvenile Atlantic salmon. - In: Ecological and physiological

studies of White Sea hydrobionts. [*In Russian*]. Leningrad, Publ. Institute of Zoology of the Academy of Sciences of the USSR, 1989, p. 126 -144.

68. ***Salmov V. Z.*** The significance of natural and artificial reproduction to the salmon population of the Kola river. - *Trudy PINRO*, 1981, issue 45, p. 94 -111.

69. ***Safonov N. V.*** The behaviour of third-year salmon in hatchery conditions. - In: Problems in the study of the rational utilization and conservation of the natural resources of the White Sea. [*In Russian*]. Leningrad, Publ. GKNT SSSR [*Gosudarstvennyi komitet Soveta Ministrov SSSR po nauke i tekhnike* - State Committee of the Council of Ministers of the USSR for Science and Technology], 1987, p. 352 - 354.

70. ***Safonov N. V., Derzhinskaya I. A. and Kharenko N. N.*** Daily locomotor activity of smolts of the Atlantic salmon. - In: Problems in the biology and ecology of the Atlantic salmon. [*In Russian*]. Leningrad, Publ. "*Nauka* ", 1985, p. 107 -119.

71. ***Safonov N. V., Orlov A. V., Seryapin S. A. and Belousov A. N.*** Rearing juvenile fish with the aid of the "*Turnir*" device. - *Rybnoe Khozyaistvo*, 1988, No. 9, p. 39 - 42.

72. ***Safonov N. V., Sushe T. A. and Chernitskii A. G.*** The state of the fins of juvenile salmon that have grown in different hatchery and natural conditions. - *Voprosy ikhtiologii* , 1990, vol. 30, issue 5, p. 801 - 809.

73. ***Sakhonchik A. K.*** The downstream migration of salmon in the rivers of Arkhangel'sk oblast. - In: Reports of proceedings of the symposium on the natural and artificial reproduction of the Atlantic salmon and on its fishery. [*In Russian*]. Moscow, Publ. *Glavrybvod* [*Glavnoe upravlenie po okhranie i vosproizvodstvu rybnykh zapasov i regulirovaniyu rybolovstva Ministerstva rybnogo khozyaistva SSSR* - Main Directorate for the Conservation and Reproduction of Fish Stocks and Regulation of Fisheries of the Ministry of the Fishing Industry of the USSR], 1971, p. 70 -71.

74. ***Skatkin P. N.*** Biological foundations of artificial fish breeding. [*In Russian*]. Moscow, Publ. Academy of Sciences of the USSR, 1962, 244 pp.

75. ***Smirnov A. I.*** Instructions on the artificial propagation of Pacific salmons. *Rybnoe Khozyaistvo* , 1963, No. 9, 62 pp.

76. ***Smirnov Yu. A.*** The freshwater salmon. Ecology, reproduction, utilization. [*In Russian*]. Leningrad, "*Nauka* " Publ., 1979, 156 pp.

77. ***Smirnov Yu. A., Shustov Yu. A., Kuz'min O. G. and Yakovenko M. Ya.*** Some aspects of the ecology of juvenile salmon in connection with the problem of increasing the productivity of the spawning and growth areas. - Trudy PINRO, 1977, No. 32, p. 109 -118.

78. ***Smirnov Yu. A., Shustov Yu. A. and Shchurov I. L.*** A study of hatchery-reared salmon parr in connection with their release into the river. - *Voprosy ikhtiologii* , 1983, vol. 23, issue 1, p. 97 -102.

79. ***Smirnov Yu. A., Shustov Yu. A. and Shchurov I. L.*** Conditions of habitation of the wild and the hatchery-reared juvenile salmon in the Kola river (Kola peninsula). - In: Problems in the biology and ecology of the Atlantic salmon. [*In Russian*]. Leningrad, Publ. "*Nauka*", 1985, p. 130-148.

80. ***Smirnov Yu. A., Shustov Yu. A., Shchurov I. L. et al.*** An attempt to change the order of the release of the production of the Vygskii fish hatchery to increase the fishery return of the salmon. - In: Questions concerning the salmon industry in the European North. [*In Russian*]. Petrozavodsk, Publ. of the Karelian Branch of the Academy of Sciences of the USSR, 1987, p. 75-78.

81. ***Tamarin A. E. and Chernitskii A. G.*** Changes in the morphometric indices during smoltification of the sea trout. [*In Russian*]. Apatity, Publ. of the Kola Branch of the Academy of Sciences of the USSR, 1988, 6 pp.

82. ***Tikhii M. I.*** Concerning the piscicultural coefficient. - *Izvestiya Gosudarstvennogo instituta opytnoi agrokhimii*, 1924, vol. 2, No. 1, p. 17-25.

83. ***Chebanova V. V., Orlov A. B. and Safonov N. V.*** Preliminary data on the feeding and food behaviour of wild and hatchery-reared downstream migrants of the salmon in the Luven'ga river. - In: The feeding of marine fishes and the use of the food base as a forecasting element. [*In Russian*]. Publ. *PINRO*, 1988, p. 23-25.

84. ***Chernitskii A. G.*** The state of the chloride cells in different stags of the life cycle of the Baltic salmon. - *Voprosy ikhtiologii*, 1979, vol. 19, issue 6, p. 1114-1119.

85. ***Chernitskii A. G.*** The adaptive significance of smoltification in the Atlantic salmon. *Zhurnal evolyutsionnoi biokhimii i fiziologii*, 1983, vol. 19, No. 2, p. 186-190.

86. ***Chernitskii A. G.*** The functional state of the chloride cells of the salmon in various stages of the life cycle. - In: Studies on the population biology and ecology of salmonid fishes in Northern bodies of water. [*In Russian*]. Leningrad, Publ. Institute of Zoology of the Academy of Sciences of the USSR, 1985 a, p. 26-37.

87. ***Chernitskii A. G.*** The migration behaviour and state of the osmoregulatory system of smolts of the Atlantic salmon. - In: Morphology and systematics of salmonid fishes. [*In Russian*]. Leningrad, Publ. Institute of Zoology of the Academy of Sciences of the USSR, 1985 b, p. 110-118.

88. ***Chernitskii A. G.*** The tasks of salmon reproduction and the tasks of salmon propagation. - In: Problems in the study, rational utilization and conservation of natural resources of the White Sea. [*In Russian*]. Arkhangel'sk, Publ. PINRO, 1985 v, p. 276-278.

89. ***Chernitskii A. G. and Loenko A. A.*** The state of the osmoregulatory system and possible pathways of differentiation of different forms of the Atlantic salmon. - *Voprosy ikhtiologii*, 1983, vol. 23, issue 6, p. 974-983.

90. ***Chernitskii A. G. and Shterman L. Ya.*** Distinctive characteristics of the osmoregulation of migrating juveniles of the Atlantic salmon. - *Voprosy ikhtiologii*, 1981, vol. 21, issue 3, p. 498-503.

91. ***Chernitskii A. G., Loenko A. A. and Popov A. P.*** The release of juvenile salmon in the Niva river: first results. [*In Russian*]. Apatity, Publ. of the Kola Scientific Centre of the Academy of Sciences of the USSR, 1989, 10 pp.

92. ***Cherfas B. I.*** Pisciculture in natural bodies of water. [*In Russian*]. Moscow, Publ. *Pishchepromizdat* [*Gosudarstvennoe nauchno-tekhnicheskoe izdatel'stvo pishchevoi promyshlennosti* - State Scientific and Technical Publishing House of the Food Industry], 1940, 210 pp.

93. ***Chechenkov A. V., Movchan. V. A. and Ryzhkov L. P.*** Morphophysical changes in the necrotic fins of juvenile salmon during artificial rearing. -In: The study and management of bodies of water in the Baltic coastal region and Byelorussia, Vol. 1, [*In Russian*]. Riga, Publ. "*Zinatne*", 1979, p.179-181.

94. ***Shvarts S. S.*** Ecological patterns of evolution. [*In Russian*]. Moscow, Publ. "*Nauka*", 1980, 278 pp.

95. ***Shustov Yu. A.*** Ecology of juvenile Atlantic salmon. [*In Russian*]. Petrozavodsk, Karelia, 1983, 152 pp.

96. ***Shustov Yu. A., Shchurov I. L. and Smirnov Yu. A.*** The behaviour and distribution of wild and hatchery-reared juvenile salmon in small rivers on the Kola peninsula. - *Sbornik nauchnykh trudov GosNIORKha*, 1981, Issue 163, p. 101-113.

97. ***Shchurov I. L., Smirnov Yu. A. and Shustov Yu. A.*** Characteristics of the adaptation of hatchery-reared juvenile salmon to river conditions. I. Possibilities for the training of juvenile salmon in hatchery conditions. - *Voprosy ikhtiologii*, 1986, vol. 26, issue 2, p. 317-320.

98. ***Shchurov I. L., Smirnov Yu. A. and Shustov Yu. A.*** Characteristics of the adaptation of hatchery-reared juvenile salmon to river conditions. II. Behaviour and feeding of trained hatchery-reared juvenile salmon in the river. - *Voprosy ikhtiologii*, 1986, vol. 26, issue 5, p. 871-874.

99. ***Yakovenko M. Ya., Neklyudov M. N. and Loenko A. A.*** Reproduction of the Atlantic salmon in the Por'ya river. - In: Biological resources of the White Sea and inland bodies of water in the European North (seminar data) [*In Russian*] - Petrozavodsk, Publ. of the Karelian Branch of the Academy of Sciences of the USSR, 1981, p. 107-110.

100. ***Yandovskaya N. I., Leizerovich Kh. A., Ostroumova I. N. et al.*** Hatchery reproduction of salmon. - *Trudy Karel'skogo otdela GosNIORKha*, 1968, vol. 5, Issue 2, p. 75-80.

101. ***Yandovskaya N. I., Kazakov R. V. and Leizerovich Kh. A.*** Instructions for the propagation of Atlantic salmon. [In Russian]. Leningrad, Publ. *GosNIORKh*. 1979, 96 pp.

105. ***Alm G.*** Salmon (*Salmo salar*) and salmon breeding in various countries. [*In German*] *Archiv für Hydrobiologie*, 1928, B. 19, N 1, p. 247-294.

ЛИТЕРАТУРА

1 АНТОНОВА В.П. Условия ската и биологическая характеристика покатной молоди семги р.Кедвы (Печорский бассейн). – В кн.: Биологические проблемы Севера. Ч.2. Магадан, изд. Ин-та биологических проблем Севера, 1983, с.142-143.

2 БАКШТАНСКИЙ Э.Л., НЕСТЕРОВ В.Д. Поведение заводских покатников атлантического лосося после периода адаптации к естественным условиям. – В кн.: Экология и воспроизводство проходных лососевых рыб в бассейнах Белого и Баренцева морей. Мурманск, изд. ПИНРО, 1985, с.88-100.

3 БАКШТАНСКИЙ Э.Л., ЧЕРНИЦКИЙ А.Г. Экологические пути повышения эффективности разведения атлантического лосося. – В кн.: Биологические основы развития лососевого хозяйства в водоемах СССР. М., Наука, 1983, с.156-170.

4 БАКШТАНСКИЙ Э.Л., НЕСТЕРОВ В.Д., СИМУКОВ Ю.А. О состоянии лососеводства в Мурманской и Архангельской областях. – В кн.: Лососевидные рыбы. Л., Наука, 1980, с.192-206.

5 БАКШТАНСКИЙ Э.Л., НЕСТЕРОВ В.Д., ЧЕРНИЦКИЙ А.Г. Рекомендации по выпуску молоди атлантического лосося и кумжи. – М., изд.ВНИРО, 1981, 29 с.

6 БАРАННИКОВА И.А. Функциональные основы миграции рыб. Л., Наука, 1975, 210 с.

7 БЕРЕЗОВСКИЙ А.И. К вопросу об эффективности и путях реконструкции искусственного разведения проходных рыб. – Рыб. хоз-во, 1933, № 2, с.5-7.

8 БОГДАНОВ Г.А., ШЕВЦОВА Э.Е. Эффективность работы лососевых рыбоводных заводов за рубежом. – Обзорная информация, сер. Рыбохозяйственное использование внутренних водоемов. М., изд. ЦНИИТЭ МРХ, 1978, вып.4, 40 с.

9 БУГАЕВ В.Ф., ПЕРВОЗВАНСКИЙ В.Я., ШУСТОВ Ю.А., ЩУРОВ И.Л. Выедание щукой заводской молоди семги в реке Кереть. – Рыб. хоз-во, 1986, № 1, с.51-52.

10 БУГАЕВ В.Ф., ШУСТОВ Ю.А., ЩУРОВ И.Л. Особенности ската заводской молоди семги в реке Кереть (бассейн Белого моря). – Вопр. ихтиологии, 1987, т.27, вып. 6, с.1035-1037.

11 БУХАНЕВИЧ И.Б., ЭРМАН Л.А. Методические указания по определению коэффициента промыслового возврата волжских осетровых. М., изд.ВНИРО, 1983, 33 с.

12 ВЕРНИДУБ М.Ф. Экстерьер молоди семги и его изменения в процессе роста. – В кн.: Биология промысловых рыб внутренних водоемов северной части европейской территории СССР. Мурманск, изд.ПИНРО, 1977, с.119-131.

13 ВЕРНИДУБ М.Ф., ЯНДОВСКАЯ Н.И. Инструкция по выдерживанию производителей, сбору, оплодотворению и подращиванию личинок лосося в условиях северо-запада СССР. М., Пищепромиздат, 1955, 38 с.

14 ГАЛКИН Г.Г. Выживаемость и рост искусственно выращенной молоди балтийского лосося в речной период ее жизни. – Изв. ГосНИОРХа, 1961, т.51, с.15-27.

15 ГОЛЬДМАН Р.С., ЧИПУЛИС В.П. Техническая диагностика цифровых устройств. М., Энергия, 1976, 224 с.

16 ГРИММ О. Беседы по рыбоводству. СПб., тип. В.Демакова, 1883, 54 с.

17 ГРУЗДЕВ А.И., СИДОРОВ В.С., СМИРНОВ Ю.А., ЧЕЧЕНКОВ А.В. Активность изоферментов лактатдегидрогеназы при некрозе плавников у молоди семги. – Вопр. ихтиологии, 1983, т.23, вып. 4, с.661-666.

18 ДИРИН Д.К. О миграции и возрасте смолтов. – В кн.: Повышение продуктивности и рациональное использование биологических ресурсов Белого моря. Л., изд. Зоол. ин-та АН СССР, 1982, с.105-108.

19 ЕВРОПЕЙЦЕВА Н.В. Переход в покатное состояние и скат молоди лососей. – Уч. зап. ЛГУ, 1957, вып. 44, № 228, с.117-154.

20 ЕРМОЛАЕВ Г.И. Исследование ската молоди лосося р.Шуи. – В кн.: Тезисы докладов 2-ой республиканской конференции молодых ученых по рыбохозяйственным исследованиям внутренних водоемов. Петрозаводск, изд.СеврыбНИИпроект, 1980, с.36-38.

21 ЕРМОЛАЕВ Г.И. Катадромная миграция дикой и заводской молоди атлантического лосося в Карелии. – Вопр.ихтиологии, 1988, т.28, вып.3, с.326-403.

22 ЗАДОРИНА В.М. Гидробиологическая характеристика некоторых рек Кольского полуострова. – В кн.: Экология и воспроизводство проходных лососевых рыб в бассейнах Белого и Баренцева морей. Мурманск, изд.ПИНРО, 1985, с.138-148.

23 ЗЕЛИНСКИЙ Ю.П. О промысловом возврате семги заводского воспроизводства. – Рыб. хоз-во, 1979, № 11, с.30-31.

24 КАЗАКОВ Р.В. Разведение атлантического лосося. 11. Эффективность работы рыбоводных заводов. – Сб.научн.тр. ГосНИОРХа, 1981, № 163, с.13-23.

25 КАЗАКОВ Р.В. Биологические основы разведения атлантического лосося. М., Лег. и пищ. пром-сть, 1982, 144 с.

26 КАЗАКОВ Р.В. Сравнительная морфологическая характеристика смолтов кумжи и семги из р.Пялицы (Белое море). – Сб.научн. тр. ГосНИОРХа, 1987, № 263, с.68-125.

27 КАЗАКОВ Р.В., КОЗЛОВ В.В. Количественная оценка степени серебрения молоди атлантического лосося природного и заводского происхождения. – В кн.: Систематика и морфология лососевидных рыб. Л., изд.Зоол.ин-та АН СССР, 1985, с.119-129.

28 КАЗАКОВ Р.В., МИНИНА Е.В. Особенности биомеханики кожи молоди семги заводского и природного происхождения в период смолтификации. – Сб.научн.тр. ГосНИОРХа, 1984, № 220, с.3-13.

29 КАЗАКОВ Р.В., СЕМЕНОВА О.В. Морфологическая характеристика заводской и природной молоди семги. – В кн.: Морфология и экология рыб. Л., изд.Зоол. ин-та АН СССР, 1986, с 75–86.

30 КИРПИЧНИКОВ В.С. Генетические основы селекции рыб. Л., Наука, 1979, 393 с.

31 КИСЕЛЕВ В.К., КИСЕЛЕВА Р.А. Экономика воспроизводства рыбных запасов. М., Лег. и пищ. пром-сть, 1983, 192 с.

32 КОЖИН Н.И. Коэффициент промыслового возврата. – Тр. ВНИРО, 1951, т.19, с.127–132.

33 КОСТЫЛЕВ Ю.В., ЕРМОЛАЕВ Г.И. Методические указания по выпуску молоди атлантического лосося, выращиваемой на рыбоводных заводах Карелии. Петрозаводск, изд.Севрыбниипроект, 1983, 14 с.

34 КОСТЫЛЕВ Ю.В., ВАЛЕТОВ В.А., ЕРМОЛАЕВ Г.И. Экологические основы повышения эффективности воспроизводства озерного лосося в Карельской АССР. – В кн.: Вопросы естественного воспроизводства и морфофизиологические особенности онтогенеза озерного лосося при искусственном разведении. Мурманск, изд.ПИНРО, 1980, с.3–28.

35 КРУГЛОВА А.Н. Зоопланктон малых лососевых рек Кольского полуострова. – В кн.: Вопросы лососевого хозяйства на европейском Севере. – Петрозаводск, изд.Карельского филиала АН СССР, 1987, с.61–64.

36 КУЗЬМИН О.Г. К биологии семги малых лососевых рек Восточного Мурмана. – В кн.: Экология и воспроизводство проходных лососевых рыб в бассейнах Белого и Баренцева морей. Мурманск, изд.ПИНРО, 1985, с.25–41.

37 КУЗЬМИН О.Г., СМИРНОВ Ю.А. Условия обитания и рост молоди семги в малых реках Кольского полуострова. – Вопр.ихтиологии, 1982, т.22, вып.5, с.773–781.

38 ЛЕВИНА Е.М., ЛОЕНКО А.А., ЧЕРНИЦКИЙ А.Г. Требования к транспортным средствам для выпуска молоди атлантического лосося. – В кн.: Экология, биологическая продуктивность и вопросы марикультуры морей Северной Европы. Апатиты, изд. Кольского научного центра АН СССР, 1990, с.102–104.

39 ЛЕЩЕВА Т.С., ЖУЙКОВ А.Ю. Обучение рыб. М., Наука, 1989, 109 с.

40 ЛОЕНКО А.А. Идентификация заводской молоди семги по структуре чешуи. – В кн.: Исследования биологии, морфологии и физиологии гидробионтов. Апатиты, изд.Кольского филиала АН СССР, 1983, с.42–44.

41 ЛОЕНКО А.А. Семга р.Лувеньга естественного и заводского воспроизводства. – Рыб. хоз-во, 1985 а, № 1, с.30–33.

42 ЛОЕНКО А.А. К вопросу об эффективности работы Кандалакшского рыбоводного завода. – В кн.: Экология и воспроизводство проходных лососевых рыб в бассейнах Белого и Баренцева морей. Мурманск, изд.ПИНРО, 1985 б, с.101–110.

43 ЛОЕНКО А.А. Сравнительный анализ работы лососевых заводов Мурманской области. – В кн.: Состояние и перспективы развития лососевого хозяйства европейского Севера. Мурманск, изд.ПИНРО, 1986, с.68–76.

44 ЛОЕНКО А.А., ЧЕРНИЦКИЙ А.Г. Особенности миграционного поведения молоди семги после выпуска с Кандалакшского рыбоводного завода в реку Лувеньга. – Редкол. Вест. ЛГУ. Сер. Биология. Л., 1980, 16 с. Рукопись деп. в ВИНИТИ 14.08.80 г., № 3656-80. Деп.

45 ЛОЕНКО А.А., ЧЕРНИЦКИЙ А.Г. Факторы, влияющие на переход в миграционное состояние молоди семги, выпущенной с рыбоводных заводов. – Вопр. ихтиологии, 1984, т.24, вып.2, с.307-315.

46 ЛОЕНКО А.А., ЧЕРНИЦКИЙ А.Г. Сравнительный анализ смолтов семги и кумжи. 1. Пол, возраст и размер смолтов. – В кн.: Проблемы биологии и экологии атлантического лосося., Л., Наука, 1985, с.163-173.

47 ЛОЕНКО А.А., ЧЕРНИЦКИЙ А.Г. Сравнительный анализ миграции смолтов семги и кумжи. – Вопр. ихтиологии, 1986, т.26, вып.5, с.795-801.

48 ЛОЕНКО А.А., ХУЗИН Р.Ш., ЧЕРНИЦКИЙ А.Г. Соотношение размерных параметров молоди семги. – Рыб. хоз-во, 1982, № 10, с.35-36.

49 ЛОЕНКО А.А., ПОНОМАРЕВ Ю.А., МИТЬКОВ Ю.О. Предварительные результаты по эффективности работы Княжегубского рыбоводного завода. – В кн.: Проблемы изучения, рационального использования и охраны природных ресурсов Белого моря. Л., изд.ГКНТ СССР, 1987, кн.2, с.330-332.

50 МАЛИКОВА Е.М., КОТОВА Н.И., РЕЗНИКОВА Н.С. Выращивание молоди балтийского лосося на рыбоводных заводах. Рига, Зинатне, 1969, 36 с.

51 МАРТЫНОВ В.Г. Семга уральских притоков Печоры. Экология, морфология, воспроизводство. Л., Наука, 1983, 127 с.

52 МЕЛЬНИКОВА М.Н. Некоторые особенности молоди семги ряда рек бассейна Белого моря. – Вопр.ихтиологии, 1970, т.10, вып.3, с.442-451.

53 МИТАНС А.Р. Условия смолтификации, динамика ската и численности покатников лосося р.Салацы. – В кн.: Рыбохозяйственные исследования в бассейне Балтийского моря. Рига, Зинатне, 1967, № 2, с.35-52.

54 МИТАНС А.Р. Некоторые характеристики речных и заводских покатников латвийского лосося. – В кн.: Рыбохозяйственные исследования в бассейне Балтийского моря. Рига, Зинатне, 1968, № 4, с.160-182.

55 МИТАНС А.Р. Поведение, питание и рост заводской молоди лосося после ее выпуска в реку. – В кн.: Рыбохозяйственные исследования в бассейне Балтийского моря. Рига, Зинатне, 1970, № 7, с.102-123.

56 НИКАНОРОВ С.И., ОФИЦЕРОВ М.В., ВИТВИЦКАЯ Л.В., ЛОЕНКО А.А. Неконтролируемый генетический отбор лососей. – Рыб. хоз-во, 1989, № 1, с.54-55.

57 НУСЕНБАУМ Л.М. Состояние и пути рационализации заводского воспроизводства семги. – Вест. ЛГУ, 1950, № 8, с.117-128.

58 НУСЕНБАУМ Л.М. Исследование покатной молоди семги. – Рыб. хоз-во. 1953, № 9, с.21-25.

59 ПЕТРЕНКО Л.А. Сравнительная характеристика речной и заводской молоди семги в реке. – Вопр. ихтиологии, 1964, т.4, вып.2, с.342-347.

60 ПЕТРЕНКО Л.А. Эффективность искусственного воспроизводства атлантического лосося. – Изв. ГосНИОРХа, 1976, № 112, с.3-20.

61 ПЕТРЕНКО Л.А. Некоторые пути повышения эффективности заводского разведения атлантического лосося. – В кн.: Лососевидные рыбы. Л., Наука, 1980, с.211-214.

62 ПОСТАНОВЛЕНИЕ СОВЕЩАНИЯ .– В кн.: Труды совещания по рыбоводству, созванного при департаменте земледелия в 1913 г., 1914, ч.1, СПб, тип. Киршбаума, с.21-63.

63 ПРОТАСОВ А.А. Биотехника искусственного разведения лососевых до покатной стадии. М., изд. ВНИРО, 1958, 60 с.

64 РАУШЕНБАХ Ю.О. Экогенез домашних животных. М., Наука, 1985, 198 с.

65 РЫЖКОВ Л.П., ПОПОВА Э.К., ПОЛИНА А.В. и др. Инструкция по инкубации икры и выращиванию молоди пресноводного лосося в оптимальных температурных условиях. Петрозаводск, изд. СевНИОРХа, 1973, 29 с.

66 САЛМАНОВ А.В. Остеологические особенности заводской и природной молоди семги из р.Лувеньга. – В кн.: Морфология и экология рыб. Л., изд. Зоол. ин-та АН СССР, 1986, с.87-98.

67 САЛМАНОВ А.В. Анализ изменчивости морфометрических показателей у заводской и природной молоди атлантического лосося. – В кн.: Экологические и физиологические исследования беломорских гидробионтов. Л., изд. Зоол. ин-та АН СССР, 1989, с.126-144.

68 САЛМОВ В.З. Значение естественного и искуственного воспроизводства для стада семги р.Кола. – Тр.ПИНРО, 1981, вып. 45, с.94-111.

69 САФОНОВ Н.В. Поведение трехлеток семги в заводских условиях. – В кн.: Проблемы изучения рационального использования и охраны природных ресурсов Белого моря. Л., изд.ГКНТ СССР, 1987, с.352-354.

70 САФОНОВ Н.В., ДЕРЖИНСКАЯ И.А., ХАРЕНКО Н.Н. Суточная двигательная активность смолтов атлантического лосося. – В кн.: Проблемы биологии и экологии атлантического лосося, Л., Наука, 1985, с.107-119.

71 САФОНОВ Н.В., ОРЛОВ А.В., СЕРЯПИН С.А., БЕЛОУСОВ А.Н. Выращивание молоди рыб с помощью устройства "Турнир". – Рыб. хоз-во, 1988, № 9, с.39-42.

72 САФОНОВ Н.В., СУШЕ Т.А., ЧЕРНИЦКИЙ А.Г. Состояние плавников молоди семги, выросшей в различных заводских и природных условиях. – Вопр. ихтиологии, 1990, т.30, вып. 5, с.801-809.

73 САХОНЧИК А.К. Скат молоди семги на реках Архангельской области. – В кн.: Тезисы докладов симпозиума по естественному и искусственному воспроизводству атлантического лосося и его промыслу. М., изд.Главрыбвода, 1971, с.70-71.

74 СКАТКИН П.Н. Биологические основы искусственного рыборазведения. М., Изд-во АН СССР, 1962, 244 с.

75 СМИРНОВ А.И. Инструкция по искусственному разведению тихоокеанских лососей. М., Рыб. хоз-во, 1963, 62 с.

76 СМИРНОВ Ю.А. Пресноводный лосось. Экология, воспроизводство, использование. Л., Наука, 1979, 156 с.

77 СМИРНОВ Ю.А., ШУСТОВ Ю.А., КУЗЬМИН О.Г., ЯКОВЕНКО М.Я. Некоторые аспекты экологии молоди семги в связи с проблемой повышения производительности нерестово-выростных угодий. - Тр.ПИНРО, 1977, № 32, с.109-118.

78 СМИРНОВ Ю.А., ШУСТОВ Ю.А., ЩУРОВ И.Л. Изучение заводских пестряток лосося в связи с их выпуском в реки. - Вопр. ихтиологии, 1983, т.23, вып.1, с.97-102.

79 СМИРНОВ Ю.А., ШУСТОВ Ю.А., ЩУРОВ И.Л. Условия обитания дикой и заводской молоди семги в реке Коле (Кольский п-ов). - В кн.: Проблемы биологии и экологии атлантического лосося. Л., Наука, 1985, с.130-148.

80 СМИРНОВ Ю.А., ШУСТОВ Ю.А., ЩУРОВ И.Л. и др. Опыт изменения порядка выпуска продукции Выгского рыбоводного завода для повышения промыслового возврата семги. - В кн.: Вопросы лососевого хозяйства на европейском Севере. Петрозаводск, изд. Карельского филиала АН СССР, 1987, с.75-78,

81 ТАМАРИН А.Е., ЧЕРНИЦКИЙ А.Г. Изменения морфометрических показателей при смолтификации кумжи. Апатиты, изд. Кольского филиала АН СССР, 1988, 6 с.

82 ТИХИЙ М.И. О рыбоводном коэффициенте. - Изв. Гос. ин-та опытной агрохимии, 1924, т.2, № 1, с.17-25.

83 ЧЕБАНОВА В.В., ОРЛОВ А.Б., САФОНОВ Н.В. Предварительные данные по питанию и пищевому поведению диких и заводских покатников семги в р.Лувеньга. - В кн.: Питание морских рыб и использование кормовой базы как элементы прогнозирования. Мурманск, изд. ПИНРО, 1988, с.23-25.

84 ЧЕРНИЦКИЙ А.Г. Состояние хлоридных клеток на различных этапах жизненного цикла балтийского лосося. - Вопр. ихтиологии, 1979, т.19, вып.6, с.1114-1119.

85 ЧЕРНИЦКИЙ А.Г. Адаптивное значение смолтификации атлантического лосося. - Журн. эволюц. биохимии и физиологии, 1983, т.19, № 2, с.186-190.

86 ЧЕРНИЦКИЙ А.Г. Функциональное состояние хлоридных клеток семги на разных этапах жизненного цикла. - В кн.: Исследования популяционной биологии и экологии лососевых рыб водоемов Севера. Л., изд.Зоол.ин-та АН СССР, 1985 а, с.26-37.

87 ЧЕРНИЦКИЙ А.Г. Миграционное поведение и состояние осморегуляторной системы смолтов атлантического лосося. - В кн.: Морфология и систематика лососевидных рыб. Л., изд.Зоол.ин-та АН СССР, 1985 б, с.110-118.

88 ЧЕРНИЦКИЙ А.Г. О задачах воспроизводства и задачах разведения семги. - В кн.: Проблемы изучения, рационального использования и охраны природных ресурсов Белого моря. Архангельск, изд. ПИНРО, 1985 в, с.276-278.

89 ЧЕРНИЦКИЙ А.Г., ЛОЕНКО А.А. Состояние осморегуляторной системы и возможные пути дифференциации различных форм атлантического лосося. – Вопр. ихтиологии, 1983, т.23, вып.6, с.974–983.

90 ЧЕРНИЦКИЙ А.Г., ШТЕРМАН Л.Я. Особенности осморегуляции мигрирующей молоди атлантического лосося. – Вопр. ихтиологии, 1981, т.21, вып. 3, с.498–503.

91 ЧЕРНИЦКИЙ А.Г., ЛОЕНКО А.А., ПОПОВ А.П. Выпуск молоди семги в реку Нива: первые результаты. Апатиты, изд.Кольского научного центра АН СССР, 1989, 10 с.

92 ЧЕРФАС Б.И. Рыбоводство в естественных водоемах. М., Пищепромиздат, 1940, 210 с.

93 ЧЕЧЕНКОВ А.В., МОВЧАН В.А., РЫЖКОВ Л.П. Морфофизические изменения у пораженной некрозом плавников молоди лосося при искусственном выращивании. – В кн.: Изучение и освоение водоемов Прибалтики и Белоруссии.Т.1, Рига, Зинатне, 1979, с.179–181.

94 ШВАРЦ С.С. Экологические закономерности эволюции. М., Наука, 1980, 278 с.

95 ШУСТОВ Ю.А. Экология молоди атлантического лосося. Петрозаводск, Карелия, 1983, 152 с.

96 ШУСТОВ Ю.А., ЩУРОВ И.Л., СМИРНОВ Ю.А. Поведение и расселение дикой и заводской молоди семги в малых реках Кольского полуострова. – Сб. научн.тр. ГосНИОРХа, 1981, вып.163, с.101–113.

97 ЩУРОВ И.Л., СМИРНОВ Ю.А., ШУСТОВ Ю.А. Особенности адаптации заводской молоди семги к речным условиям после повышения физической выносливости рыб перед выпуском. 1. Возможности тренировки молоди в заводских условиях. – Вопр. ихтиологии, 1986 а, т.26, вып.2, с.317–320.

98 ЩУРОВ И.Л., СМИРНОВ Ю.А., ШУСТОВ Ю.А. Особенности адаптации заводской молоди семги к речным условиям. П. Поведение и питание тренированной заводской молоди семги в реке. – Вопр.ихтиологии, 1986 б, т.25, вып.5, с.871–874.

99 ЯКОВЕНКО М.Я., НЕКЛЮДОВ М.Н., ЛОЕНКО А.А. Воспроизводство атлантического лосося в р.Порья. – В кн.: Биологические ресурсы Белого моря и внутренних водоемов европейского Севера (материалы семинара) – Петрозаводск, изд.Карельского филиала АН СССР, 1981, с.107–110.

100 ЯНДОВСКАЯ Н.И., ЛЕЙЗЕРОВИЧ Х.А., ОСТРОУМОВА И.Н. и др. Заводское воспроизводство семги. – Тр.Карельского отд.ГосНИОРХа, 1968, т.5, вып.2, с.75–80.

101 ЯНДОВСКАЯ Н.И., КАЗАКОВ Р.В., ЛЕЙЗЕРОВИЧ Х.А. Инструкция по разведению атлантического лосося. Л., изд. ГосНИОРХа, 1979, 96 с.

102 ABBOT J.C., DILL D.M. Patterns of agressive attack in juvenile steelhead trout (Salmo gairdneri). – Can.J.Fish.Aquat. Sci., 1985, v.45, N 11, p.1702–1706.

103 ALEXANDER D.R., GALBRAITH P. A plan to reestablish a natural population of Atlantic salmon in the Point Wolfe River, Fundy National Park. – Can. Manuscript Rep. of Fisheries and Aquat.Sci., 1982, N 1067, 8 p.

104 ALLAN J.R.N., RITTER J.A. Salmonid terminology. – J. Cons. int. explor. mer. 1977, v. 3, N 3, p.293–299.

105 ALM G. Der Lachs (Salmo salar) und die Lachszucht in verschiedenen Landern. – Arch. Hydrobiol. 1928, B. 19, N 1, s.247–294.

106 BAKSHTANSKY E.L., SAFONOV N.V., ROZHDESTVENSKAYA V.I. et al. Studies on some characteristics and destinity of hatchery young Atlantic salmon. 1979. – ICES, 1979, F:13, 24 p.

107 BAKSHTANSKY E.L., SAFONOV N.V., ROZHDESTVENSKAYA V.I. et al. Peculiarities in adaptation of hatchery and wild Atlantic salmon smolts to brackish water (13‰). – ICES, 1980, M:14, 14 p.

108 BILTON H.T., ALDERDICE D.F., SCHNUTE J.T. Influence of time and size at release of juvenile coho salmon (Oncorhynchus kisutch) on returns at maturity. – Can.J.Fish. Aquat. Sci., 1982, v.39, N 3, p.426–447.

109 BOEUF G., le ROUX A., GAIGNON J.L., HARACHE Y. Gill $(Na^+ - K^+)$ -ATPase activity and smolting in Atlantic salmon (Salmo salar L.) in France. – Aquaculture, 1985, v.45, N 1–4, p.73–81.

110 BRANNON E., FELDMANN C., DONALDSON L. University of Washington zero-age coho salmon smolt production. – Aquaculture, 1982, v.28, N 1–2, p.195–200.

111 CARLIN B. Tagging of salmon smolts in the River Lagan.– Rep. Inst. Frehswater Res. Drottningholm, 1955, v.36, p.57–74.

112 CHADWIC E.M.P., PORTER T.R., DOWNTON P. Analysis of growth of Atlantic salmon (Salmo salar) in a small Newfoundland river. – J.Fis.Res.Board.Can., 1978, v.35, N 1, p.60–68.

113 CHERNITSKY A.G. The smolt status of wild and hatchery young Atlantic salmon Salmo salar L – ICES, 1985, M:6, 15 p.

114 CHERNITSKY A.G. Quantitative evaluation of parr–smolt transformation in wild smolts and hatchery juveniles if Atlantic salmon (Salmo salar L.) by SDH activity of chloride cells. – Aquaculture, 1986, v.59, N 4, p.287–297.

115 CHRISTENSEN O. Danish Experiments with salmon smolt released into the Baltic sea from Island of Bornholm. – ICES, 1982, M:9, 7 p.

116 CLARKE W.C. Evaluation of the seawater challenge test as an index of marine survival. – Aquaculture, 1982, v,28, N 1–2, p.177–183.

117 DICKHOFF W.W., SULLIVAN C., MAHNKEN C.V.W. Methods of measuring and controlling the parr to smolt transformation (smoltification) of juvenile salmon. – NOAA Techn. Rept. NMFS, 1985, N 27, p.5–9.

118 ERIKSSON T. Migratory dehaviour of Baltic salmon (Salmo salar L.) adaptive significance of annual cycles. Umea, Umea University, Sweden, 1988, 86 p.

119 GASTON P.B. Atlantic salmon culture for restoration. US Fish and Wildlife Service, One Gateway Center Newton Corner, MA 02158, 1988, 97 p.

120 GORBMAN A., DICKHOFF W.W., MIGHELL J.L. et al. Morphological indices of developmental progress in the parr–smolt coho salmon, Oncorhynchus kisutch. – Aquaculture, 1982, v.28, N 1, p.1–19.

121 GUDJONSSON T. The releases and return of tagged salmon at Kollafjordur, Iceland. – ICES, 1970, M:6, 6 p.

122 GUDJONSSON T. Smolt rearing techhiques, stocking and tagged adult salmon recapturex in Iceland. – In: M.V.Smith, W.M. Carter (ed). International Atlantic salmon Symposium. – Int.Atl. Salmon Found., N.Y., 1973, v.4, p.227–235.

123 GUNNERØD T.B., HVIDSTEN N.A., HEGGBERGET T.G. Open sea releases of Atlantic salmon smolts, Salmo salar, in central Norway, 1973–83. – Can.J.Fish Aquat.Sci., 1988, v.45, N 8, p.1340–1345.

124 HANSEN L.P., JONSSON B. Salmon ranching experiments in the river Imsa: effects of day and night release and of seawater adaptation on recapture-rates of adults. – Rept. Inst. Freshwater Res. Drottningholm, 1986, N 63, p.47–51.

125 HAHSEN L.P., JONSSON B. Salmon ranching experiments in the River Imsa: effect of timing of Atlantic salmon migration on survival to adults. – Aquaculture, 1989, v. 82, N 1–4, p.367–373.

126 HANSEN L.P., JONSSON B., DOVING K.B. Migration of wild and hatchery reared smolts of Atlantic salmon Salmo salar L., through lakes. – J. Fish. Biol., 1984, v.25, N 5, p.617–623.

127 HARRIS G.S. (ed.) Salmon propagation in England and Wales. ARA/NWC Working group Report. L. National Water Council, 1978,62 p.

128 HESTHAGEN T., GARNAS E. Smolt age and size of Atlantic salmon Salmo salar L. and sea trout Salmo trutta L. in a Norwegian river. – Fauna norv., 1984, v.5, N 5, p.46–49.

129 HESTHAGEN T., OUSDAL J.-O., BERGHEIM A. Smolt production of Atlantic salmon (Salmo salar L.) and brown trout (Salmo trutta L.) in a small Norwegian river influenced by agricultural activity. - Pol.arch.hydrobiol., 1986, N 3-4, p.423-432.

130 HIGGINS P.J. Metabolic differences between Atlantic salmon (Salmo salar) parr and smolts. - Aquaculture, 1985, v.45, N 1-4, p.33-53.

131 HUTCHINGS J.A. Lakeword migrations by juvenile Atlantic salmon (Salmo salar). - Can. J. Fish. Aquat. Sci., 1986, v.43, N 4, p.732-741.

132 HVIDSTEN N.A., LUND R.A. Predation on hatchery-reared and wild smolts of Atlantic salmon, Salmo salar L., in the estuary of River Orkla, Norway. - J. Fish Biol., 1988, v.33, N 1, p.121-126.

133 HVIDSTEN N.A., MØKKELGJERD P.I. Predation on salmon smolts, Salmo salar L., in the estuary of the river Surna, Norway. - J. Fish Biol., 1987, v. 30, N 3, p.273-280.

134 ISAKSSON A. The improvement of returns of one-year smolts at the Kollarfiördur Experimental Fish Farm, 1971-1973.- J. Agr. Res. Icel, 1976, v.8, N 1-2, p.19-26.

135 ISAKSSON A., OSKARSSON S. Returns of comparable microtagged atlantic salmon (Salmo salar L.) of Kollafjördur stock to three salmon ranching facilities. - Rept. Inst. Freshwater Res., Drottningholm, 1986, N 63, p.58-69.

136 ISAKSSON A., RACSH T.J., POE P.H. An evaluation of smolt releases into a salmon and a non-salmon producing stream using two release methods. - Iselenz. landbunadarransok, 1978, v.10, N 2, p.100-113.

137 JENSEN K.W. Saltwater releases and saltwater adaptation of smolts of Atlantic salmon. - ICES, 1979, M:8, 10 p.

138 JENSEN A.J., JOHNSEN B.O. Different adaptation strategies of Atlantic salmon (Salmo salar) populations to extream climates with special reference to somo cold Norwegian rivers. - Can. J. Fish. Aquat. Sci., 1986, v.43, N 5, p.980-984.

139 JESSOP B.M. Investigation of the salmon (Salmo salar) smolt migration of the big salmon river, New Brunswick, 1966-1972. - Techn. report Series No Mar/T-75-1, 1975, 57 p.

140 JOHANSSON N. General problems in Atlantic salmon rearing in Sweden. - Ecol.Bull., 1981, N 34, p.75-83.

141 JONES A.N. A preliminary study of fish segregation in salmon spawning streams. - J. Fish. Biol., 1975, v.7, N 1, p.95-104.

142 KENNEDY G.J.A., STRANGE C.D., ANDERSEN R.J.D., JOHNSTON P.M. Experiments on the descent and feeding on hatchery-reared salmon smolts (Salmo salar L.) in the River Bush. - Fish. Manage, 1984, v.15, N 1, p.15-25.

143 KNUTSSON S., HOLM M. An experiment with migrating smolt of Atlantic salmon (Salmo salar). - ICES, 1977, E:61, 8 p.

144 LANGDON J.S., THORPE J.E. The ontogeny of smoltification: developmental patterns of gill Na^+/K^+ - ATPase, SDH, and chloride cells in juvenile Atlantic salmon, Salmo salar L. - Aquaculture, 1985, v.45, N 1-4, p.83-95.

145 LARSSON H.-O. The influence of predation after release on the result of salmon smolt planting. - ICES, 1977, M:44, 9 p.

146 LARSSON H.-O., LARSSON P.-O. Predation pa nyutsatt odlad smolt i Luleålven. - Swed. Saim. Res. Inst. Rep., LFI Medd, 1975, N 9, 14 p.

147 LARSSON P.-O. Size dependent mortality in salmon smolt plantings. - ICES, 1977, M:43, 9 p.

148 LEGAULT M., LALANCETTE L.M. Observations sur le comportement d'alevins de saumon (Salmo salar L.) apres leur déversement en riviere. - Bull. fr. peche et pisciculт., 1987, v.60, N 304, p.32-40.

149 LINDROTH A. The smolt migration in the river Mörrumsan (Sweden) 1963-1966. - ICES, 1977, M:8, 22 p.

150 MILLS D.H. The ecology of the young stages of the Atlantic salmon in the river Bran, Ross-shire. - Freshwat. Salm. Fish. Res.,1964, N 32, 58 p.

151 MURRAY A.R. Smolt survival and adult utilization of little Codroy River, Newfoundland, Atlantic salmon. - J. Fish. Res. Board Can., 1968, v.25, N 10, p.2165-2218.

152 OSTERDAHL L. Smolt investigation in the river Ricklean. - Swed. Salm. Res. Inst. Rep., 1964, LFI Medd., 8/1964, 7 p.

153 OTTERSTRÖM C.V. On methodical liberations of salmon and trout fry in watercoursed with special reference to the Gudenaa area. - Rep. Danish Biol. Station, 1938, v.42, p.3-32.

154 PEPPAR J.L. Atlantic salmon smolt investigations, Restigouche River system, New Brunswick. - Can. MS. Rep. Fish. Aquat. Sci., 1982, N 1641, 15 p.

155 PETERSON H.H. Adult returns to date from hatchery-reared one-yearold smolts.- In: M.V.Smith and W.M.Carter (ed.). International Atlantic salmon Symposium. - Int. Atl. Salmon Found., N.Y., 1973, v.4, p.219-226.

156 PETERSON H.H., CARLSON O.T., JONASSON S. The rearing of Atlantic salmon. Södertälje, Astra-Ewos, 1972, 39 p.

157 PIGGINS D.J., MILLS C.P.R. Comparative aspects of the biology of naturally produced and hatchery-reared Atlantic salmon smolts (Salmo salar L.). - Aquaculture, 1985, v.45, N 1-4, p.321-333.

158 POWER G. Estimates of age, growth, standing crop and production of salmonids in some north Norwegian rivers and streams. - Rept. Inst. Freshwater Res. Drottninghoim, 1973, N 53, p.78-111.

159 PYEFINCH K.A. The results of the international tagging tests, 1959-1963. - ICES, 1966, L:9, 3 p.

160 RASMUSSEN G. Liberation of trout (Salmo trutta L.) in Danish stream - EIFAC Technical Paper, 1984, 42/Suppl./1, Rome, p.164-177.

161 REINERT A. Atlantic salmon and plans for salmon ranching in the Faroe islands. - In: Sea ranching of Atlantic salmon. (ed. C.Eriksson, M.P.Ferranti, P.O.Larsson), Lisbon, 1982, p.81-89.

162 RIDDEL B.E., LEGGETT W.C. Evidence of an adaptive basis for geographic variation in body morphology and time of downstream migration of juvenile Atlantic salmon (Salmo salar).- Can. J. Fish. Aquat. Sci., 1981, v.38, N 2, p.308-320.

163 RITTER J.A. Relationship between smolt size and tag return rate for hatchery reared Atlantic salmon (Salmo salar). - ICES, 1977, M:27, 12 p.

164 ROTTIERS D.V., REDELL L.A., JOHNSON C.S. Final report on volitional movement of Atlantic salmon from self-release ponds, 1984-1987. - Proc. New England Atlantic Salmon Workshop, Roskport, Maine, March 22-23, 1988, p.79-108.

165 SAUNDERS R.L., BEILEY J.K. The role of genetics in Atlantic salmon management. - In: Atlantic salmon: its future. Farhham, Surrey, 1980, p.182-200.

166 SAUNDERS R.L., HENDERSON E.B., HARMON P.R. Effects of photoperiod on juvenile growth and smolting of Atlantic salmon and subsequent survival and growth in sea cages. - Aquaculture, 1985, v.45, N 1-4, p.55-66.

167 SCHNEIDER R., NICHOLSON B.L. Bacterial associated with fin rot deseases in hatchery-reared Atlantic salmon (Salmo salar). - Can. J. Fish. Aquat. Sci., 1980, v.37, N 10, p.1505-1513.

168 SEGARICH V. Atlantic salmon stocking methods. - Biol. Rept., US Dep. Inter., Fish and Wildlife Serv., 1989, N 12, p.28-29.

169 SEMPLE J.R., MERCER G. Point Wolfe River salmon rehabilitation: fall-fingerling stocking by helicopter, 1982-83. - Can. MS Rep. Fish. Aquat. Sci., 1987, N 1918, 7 p.

170 SHEARER W.M. Recaptures from released of hatchery-reared and wild smolts in river North Esk. - ICES, 1965, Salmon and trout commitee, N 59, 4 p.

171 STAHL G. Differences in the amount and distribution of genetic variation between natural populations and hatchery stocks of Atlantic salmon. - Aquaculture, 1983, v.33, N 1-4, p.23-32.

172 SUTTERLIN A.M., SAUNDERS R.L., HENDERSON E.B., HARMON P.R. The homing of Atlantic salmon (Salmo salar) to a marine site. - Can.Tech. Rep. Fish. Aquat. Sci., 1982, N 1058, 6 p.

173 SYMONS P.E.K. Greater dispersal of wild compared with hatchery reared juvenile Atlantic salmon released in streams. - J. Fish. Res. Bd. Can., 1969, v.26, N 7, p.1867-1876.

174 TAVE D. Effective breeding efficiency: an index to quantify the effects that different breeding programs and sex ratios have on inbreeding and genetic drift. - Progr. Fish-Cult., 1984, v.46, N 4, p.262-268.

175 THORPE J.E., MORGAN R.I.G., OTTAWAY E.M., MILES M.S. Time of divergence of growth groups between potential 1+ and 2+ smolts among siblings Atlantic salmon. - J. Fish Biol., 1980, v.17, N 1, p. 13-21.

176 VICKERS K.U. Survival of smolts from the river Bush. - ICES, 1977, M:15, 4 p.

177 VIRTANEN E. Smolting and osmoregulation of Baltic salmon, Salmo salar L., in fresh and brackish water. - Finnish Fisheries Res., 1988, v.7, N 1, p.38-65.

178 VIRTANEN E., SOIVIO A. The patterns of T_3, T_4, cortisol and $Na^+ - K^+$ - ATPase during smoltification of hatchery reared Salmo salar and comparison with wild smolts. - Aquaculture, 1985, v.45, N 1-4, p.97-109.

179 WEDEMEYER G.A., SAUNDERS R.L., CLARKE W.C. Environmental factors affecting smoltification and early marine survival of anadromous salmonids. - Mar. Fish. Rev., 1980, v.42, N 6, p.1-14.

180 WENDT C.A.G., Saunders R.L. Changes in carbohydrate metabolism in young Atlantic salmon in response to various forms of stress. - In: M.V.Smith and W.M.Carter (ed). International Atlantic salmon Symposium, Int. Atl. Salmon Found., N.Y., 1973, p.55-82.

181 YOUNGSON A.F., MCLAY H.A., OLSEN T.C. The responsiveness of the thyroid system of Atlantic salmon (Salmo salar L.) smolts to increased water velocity. - Aquaculture, 1986, v.56, N 3, p.243-255.

182 YOUNGSON A.F., HANSEN L.P., JONSSON B., NAESJE T.F. Effects of exogenous thyroxine or prior exposure to raised water-flow on the downstream movement of hatchery-reared Atlantic salmon smolts. - J.Fish. Biol. 1989, v.34, N 5, p.791-797.

SUMMARY

Destiny of salmon released by Kandalaksha hatchery in Luvenga river have been investigated for 13 years. Of 282 thousand salmon juveniles released in the river from 1978 to 1987 only 0.1% survived and returned for spawning. Recapture of wild smolts in the same years was 2.5%. The main part of released juveniles dies in the sea. Predominating part of recaptured salmon belongs to the fish stayed in the river for 1-2 years after release. Comparison of wild and hatchery juveniles showed significant differences of their age and sexual structure, size and morphometric characteristics. The conditions of release of hatchery juveniles influence the dynamics of their migration and survival in the river and in the sea.

Methods of training, selection and release of salmon juveniles in different countries are discussed as well as the criteria of estimation of salmon hatchery effectiveness.

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